
Ground Water

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Introduction

Ground water in the Livermore Valley and in the Altamont Hills is monitored regularly by LLNL. The monitoring objectives are: to assess the progress of LLNL remediation efforts in areas of known ground water contamination; to assess the effectiveness of current LLNL activities, especially waste management practices, designed to protect the environment; and to conform with the requirements of the Ground Water Protection Management Program. Remediation efforts result from LLNL actions to comply with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA; see Chapter 2 for a summary of CERCLA activities). Operational monitoring complies with waste discharge requirements issued under California's Porter-Cologne Water Quality Act. Compliance monitoring is required by numerous federal, state, and local permits (see Chapter 2, Table 2-7 for a summary of LLNL permits). Surveillance monitoring of ground water is required by DOE Order 5400.1 as part of the U.S. Department of Energy's (DOE) commitment to protect the environment at DOE sites.

For surveillance monitoring purposes, LLNL determines the number and locations of surveillance wells, the constituents of concern (COCs) to be monitored, the frequency of sampling, and the analytical methods to be used. This allows LLNL to design a comprehensive, cost-effective monitoring program. A wide range of COCs is monitored in ground water to confirm that current LLNL operations do not significantly impact local water resources and to detect any slow-to-develop contamination due to past operations. Wells at the Livermore site, the Livermore Valley, and at Site 300 in the Altamont Hills are included in LLNL's surveillance monitoring plan. The surveillance networks include private wells and CERCLA wells.

Additional ground water wells are monitored regularly to comply with state-issued permits associated with closed landfills containing solid wastes from past LLNL operations and with continuing discharges of liquid waste from current operations. This compliance monitoring uses networks of water wells that are specifically positioned and constructed to meet regulatory requirements.



8

Ground Water

LLNL's program of surveillance and compliance ground water monitoring follows an annual plan. Depending on their location and purpose, ground water wells are sampled quarterly, semiannually, or annually. Standard operating procedures (SOPs) are followed when taking samples of well water to minimize the effects of sampling on analytical results (Dibley and Depue 1996).

Ground Water Regime

Livermore Site

Physiographic Setting

The Livermore Valley is the most prominent valley within the Diablo Range. It is an east-west trending structural and topographic trough bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley is approximately 25-km long and averages 11 km in width. The valley floor is 220 m at its highest elevation along the eastern margin and gradually dips to 92 m at the southwest corner. The valley floor is covered by alluvial, lake, and swamp deposits consisting of gravels, sands, silts, and clays with an average thickness of about 100 m.

The Livermore Valley Ground Water Basin encompasses 17,000 hectares, including the uplands. The streams within the basin are ephemeral, flowing only during the October to May rainy season. The prominent streams are Arroyo del Valle, Arroyo Las Positas, Arroyo Seco, Arroyo Mocho, Alamo Creek, South San Ramon Creek, and Tassajara Creek. Arroyo del Valle and Arroyo Mocho drain the largest areas and are the largest streams. Arroyo Mocho now flows the entire year with water supplied by the Alameda County Flood Control and Water Conservation District Zone 7. The streams converge westward at Arroyo de la Laguna, which flows southward out of the valley into the Sunol Valley Ground Water Basin.

The Livermore Valley ground water system is a sequence of semiconfined aquifers. Ground water moves downslope from the valley uplands toward the east-west axis of the valley. It then flows generally westward toward the southwest portion of the basin. From there, ground water historically flowed south into the Sunol Valley Ground Water Basin. However, use of ground water within the basin has stopped the subsurface outflow since 1945. The largest quantities of ground water are pumped from the central and western portions of the Livermore Valley, where the valley fill is thickest.

The valley-fill sediments make up two aquifers: the Livermore Formation and its overlying alluvium. The Livermore formation averages about 1000 m in thickness and occupies an area of approximately 250 km². The alluvium averages about 100 m in thickness. The alluvium is the principal water-producing formation within the valley.



The quality of ground water in the Livermore Valley reflects the surface water that recharges the aquifers. The chemical character of the ground water ranges from excellent (low sodium, magnesium, or calcium bicarbonate content) to poor (high sodium chloride content). In the eastern part of the valley, poor quality ground water results from recharge via Altamont Creek, which drains marine sediments to the east of the valley. High concentrations of naturally occurring minerals there, especially boron, render this ground water unsuitable for irrigation.

Drainage Retention Basin

In 1990, a drainage basin was constructed near the center of the Livermore site to catch and retain storm water runoff. The Drainage Retention Basin (DRB) is lined to prevent infiltration in this area. Surface drainage at the Livermore site is discussed in detail in Chapter 7.

Hydrogeology

Sediment types at the Livermore site are grouped into four categories—clay, silt, sand, and gravel—based on dominant particle size. Ground water flow beneath the site is primarily in sand and gravel lenses and channels, bounded by the less permeable clays and silts. The alluvial setting has been mapped into seven hydrostratigraphic units beneath the Livermore site using data collected over the years. Hydrostratigraphic units (HSUs) can be defined as sedimentary sequences whose permeable layers show evidence of hydraulic connection. The HSUs of concern beneath the Livermore site are the Quaternary alluvial deposits of the upper Livermore member of the Livermore Formation. Hydrostratigraphic units 1B, 2, and 3A (in order of increasing depth, see **Figure 8-1**) contain contaminants, which are primarily solvents (Hoffman et al. 1997).

Based on borehole lithologic data, a series of buried sand and gravel-filled stream channels have been identified at the site. The sand and gravel deposits, which are highly permeable, are present in narrow bands at the site and are interpreted as braided stream deposits, similar to strata deposited by the present day Arroyo Mocho.

In 1996, the depth to ground water ranged from 40 m (130 ft) at the southeast corner of the site to 10 m (33 ft) at the northwest corner and 12 m (40 ft) at the northeast corner. Ground water levels have responded to variations in annual rainfall and resource use. Decreases in ground water use from the 1960s to 1985 caused the water table to rise. Heavy rains caused rises in 1986, 1993, 1994, 1995, and, 1996, while drier-than-normal winters caused declines between 1987 and 1991.



8

Ground Water

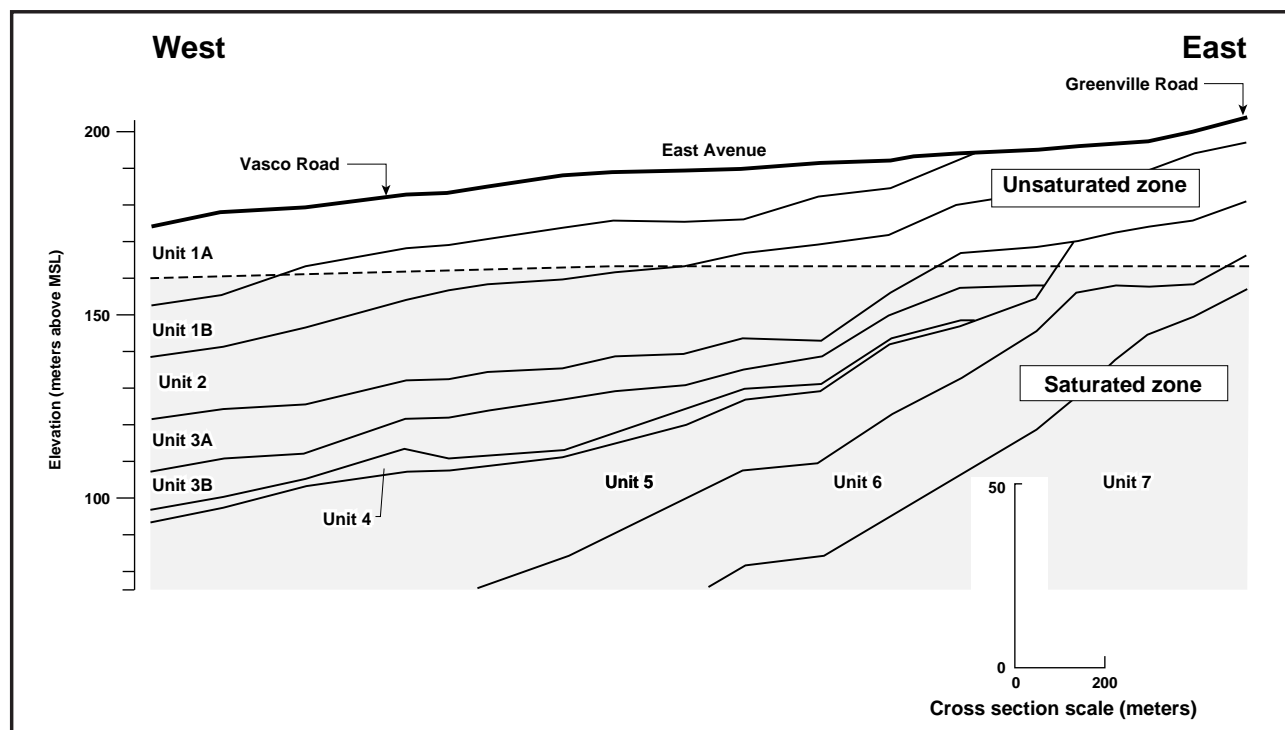


Figure 8-1. Hydrostratigraphic cross section for the Livermore site.

Ground water is recharged at the Livermore site mainly from nearby arroyos and from direct rainfall. Recharge enters primarily through the arroyos (see also Chapter 7). Ground water flow at the Livermore site is generally westward. The hydrogeology of the Livermore site is discussed in detail in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990) and Ground Water Project Reports.

The conceptual model presented in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* suggests that ground water generally flows towards two destinations from the Livermore site. Ground water from the north half flows west and northwest and eventually discharges to Arroyo Las Positas near First Street in Livermore, about 2 km northwest of the Livermore site. Ground water from the southern half flows generally westward toward the gap between the Mocho I and Mocho II subbasins, about 2 km west of the Livermore site. Ground water velocities at the Livermore site range from 15 to 20 m (49 to 66 ft) per year.

Site 300

Physiographic Setting

Site 300 is located in the Altamont Hills, which are part of the Coast Ranges Physiographic Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east.



Rocks exposed in the region are classified into three groups:

- Late Tertiary-Quaternary (0–5 million years ago)—Alluvium and semilithified sediments, mainly of continental origin.
- Early to late Tertiary (5–65 million years ago)—Shallow marine and continental sedimentary and volcanoclastic rocks.
- Jurassic-Cretaceous (65–180 million years ago)—Great Valley sequence (marine sedimentary rocks and ophiolites); Franciscan Complex (sheared and variably metamorphosed sedimentary and igneous rocks).

Distinctive blue-gray to brown weathering volcanoclastic sandstone and sandy siltstone, interbedded with light gray weathering tuffaceous claystone and conglomerate, are exposed extensively within Site 300. These rocks are mapped as the late Miocene Neroly Formation (Huey 1948; Dibblee 1980). The Neroly Formation is also present in the subsurface beneath the southeastern portion of Site 300.

The Neroly Formation is the principal hydrologic unit within Site 300 and has therefore been the focus of the detailed geologic and hydrogeologic studies conducted during recent years (summarized in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300*, hereafter referred to as Final SWRI Report [Webster-Scholten 1994]). The Neroly Formation is about 150 m thick beneath Site 300.

The active floodplain of Corral Hollow Creek lies along the southern boundary of Site 300, underlying portions of the western and eastern General Services Area (GSA). The floodplain also makes small incursions into Site 300 in the vicinity of closed landfill Pit 6. Floodplain alluvium consists dominantly of coarse cobble and boulder-bearing gravel derived from sources to the south, with lenses and local cappings of sandy silt and silty clay.

The bedrock sequence within Site 300 has been slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional fault and fracture patterns, may locally influence ground water flow within the site and have therefore been studied as part of the CERCLA investigations.

Hydrogeology

Site 300 is generally underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock is made up primarily of interbedded sandstone, siltstone, and claystone (**Figure 8-2**). Most ground water occurs in the Neroly Formation upper blue sandstone (Tnbs₂) and lower blue sandstone (Tnbs₁) aquifers. Significant ground water is also locally present in permeable Quaternary alluvium valley fill (Qa₁). Much less ground water is present in the Miocene Non-marine (Tps) unit, where it occurs as



8

Ground Water

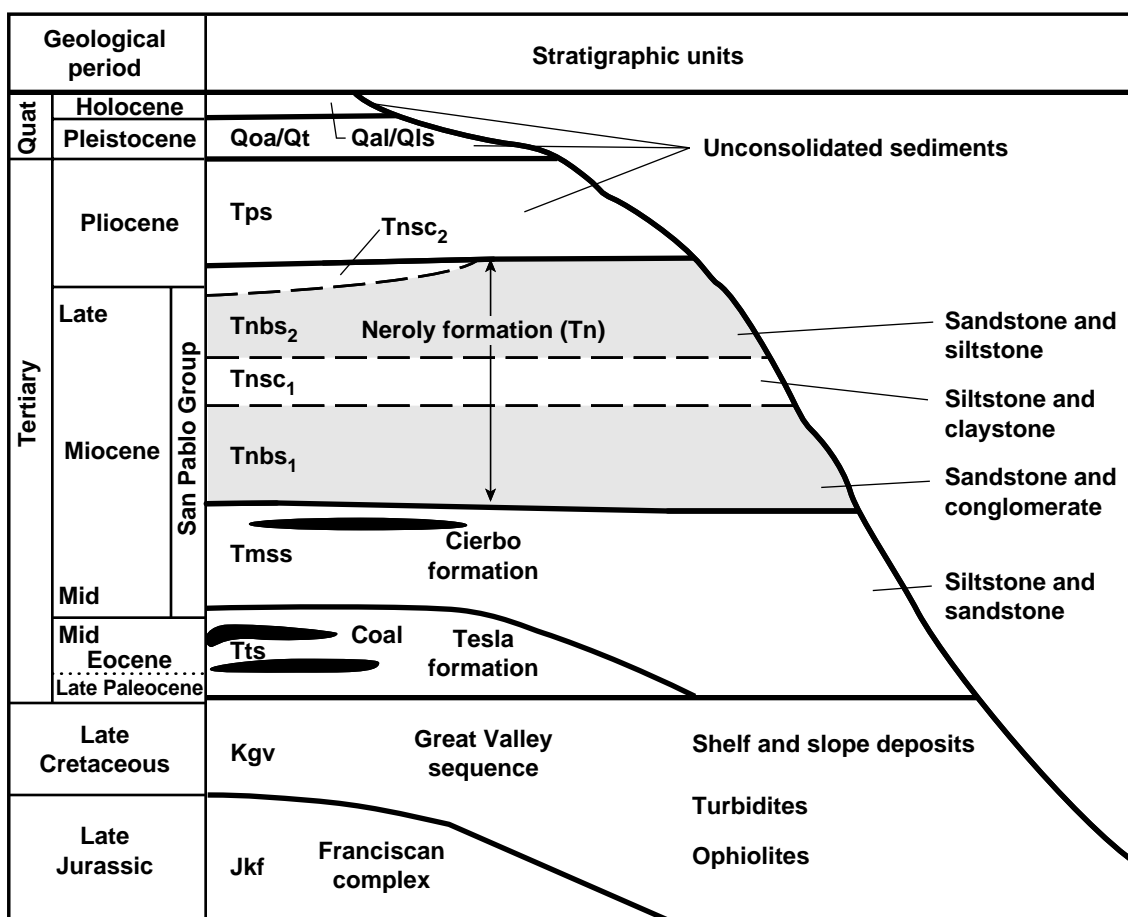


Figure 8-2. Site 300 stratigraphy. Stratigraphic codes are in standard geological notation (Webster-Scholten 1994). (For example, Tnbs₁ stands for tertiary Neroly lower blue sandstone.)

perched water-bearing zones beneath hilltops in the Buildings 833 and 834 areas, and more extensively in the Explosives Process Area. The perched water-bearing zone at Building 833 is ephemeral. Fine-grained siltstone and claystone interbeds act as aquitards, confining layers, or perching horizons. Ground water is present under confined conditions in parts of the deeper bedrock aquifers, but is generally unconfined elsewhere.

Recharge occurs predominantly in locations where saturated alluvium valley fill is in contact with underlying permeable bedrock, or where bedrock strata crop out because of structure or topography. Local recharge also occurs on hilltops, thus creating the perched water-bearing zones at Buildings 833 and 834. Low rainfall, high evapotranspiration, steep topography, and intervening aquitards generally preclude direct vertical recharge of the bedrock aquifers.



Ground water flow in most aquifers follows the attitude of the bedrock. In the northwest part of Site 300 (north of the east-west trending Patterson anticline), bedrock ground water flows generally northeast, except where it is locally influenced by ground water in alluvium-filled ravines. In the southern half of the site, bedrock ground water flows roughly south-southeast, approximately coincident with the attitude of bedrock strata.

Ground water in the Tnbs₁ aquifer is unconfined in much of the northwestern part of Site 300. In the southern Explosives Process Area, several flowing artesian wells are present. Tnbs₂ beds are present throughout most of the southeastern part of Site 300, and locally in the northern part of the site. Prior to about 1980, this unit was used as a water-supply aquifer in the southern Explosives Process Area. In the northern part of the Explosives Process Area, the Tnbs₂ is unsaturated, but saturation increases down dip toward the south. Tnbs₂ ground water in the central Explosives Process Area is under phreatic (water table) conditions; the hydraulic head increases southward, resulting in local flowing artesian conditions in Tnbs₂ wells in the southern Explosives Process Area.

The Cierbo Formation (Tmss) is saturated beneath Doall Ravine, the Building 851 Area, and the southern part of the East Firing Area. The Tmss is unsaturated or does not otherwise yield water to wells in other parts of the East and West Firing Areas, and this may be the result of swelling clays in pore spaces. The thickness of the Cierbo Formation is not well known because most boreholes are not deep enough to completely penetrate this formation. Some of the deeper wells in the GSA penetrate the uppermost Tmss. Similar to the Tnbs₁, the continuity of saturation between the northwest and southeast areas of Site 300 is undetermined. Ground water in the Tmss occurs under unconfined to artesian conditions.

The Tps unit is the youngest bedrock unit identified at Site 300 and is generally present only on hilltops. Where present, ground water is frequently perched, discontinuous, and/or ephemeral. The exception to this condition exists in the Explosives Process Area, where the extent of saturation in Tps sediments is significant. Ground water in the Tps unit is generally unconfined, although water under confined conditions does occur locally.

Quaternary alluvium (Qa₁) is present as valley fill in ravines throughout Site 300, but is saturated only in the Corral Hollow Creek stream channel, in Doall Ravine in the West Firing Area, and in southern Elk Ravine in the East Firing Area near a spring. Saturated Quaternary terrace alluvium deposits (Qt) are present in the Pit 6 Area, GSA, and Building 833 study areas; some of these occurrences may be ephemeral. Small quantities of ground water are present in some local landslide (Qls) deposits.



8

Ground Water

Surveillance Ground Water Monitoring of Livermore Valley

Livermore Site

To complement the Livermore Ground Water Project, LLNL has redesigned the surveillance monitoring program to detect possible releases from beneath the Livermore site as a whole. Monitoring of the vadose zone is not feasible in this area because most of the area is paved. Therefore, surveillance monitoring of existing ground water wells was the method of choice. This program makes use of two upgradient monitoring wells (W-008 and W-221) in the eastern portion of the site, and seven downgradient monitoring wells near and past the western boundary of the site (**Figure 8-3**). These downgradient wells are located in the regions of Treatment Facility A (W-121, W-151, and 14B1), Treatment Facility B (W-571 and W1012), and Treatment Facility C (W-373 and W-556). This configuration was implemented in 1996 to monitor the uppermost aquifers (HSUs 1B and 2) within that area. The intent of this network is to monitor for possible contaminants other than volatile organic compounds (VOCs), which are handled under the Livermore Site Ground Water Project.

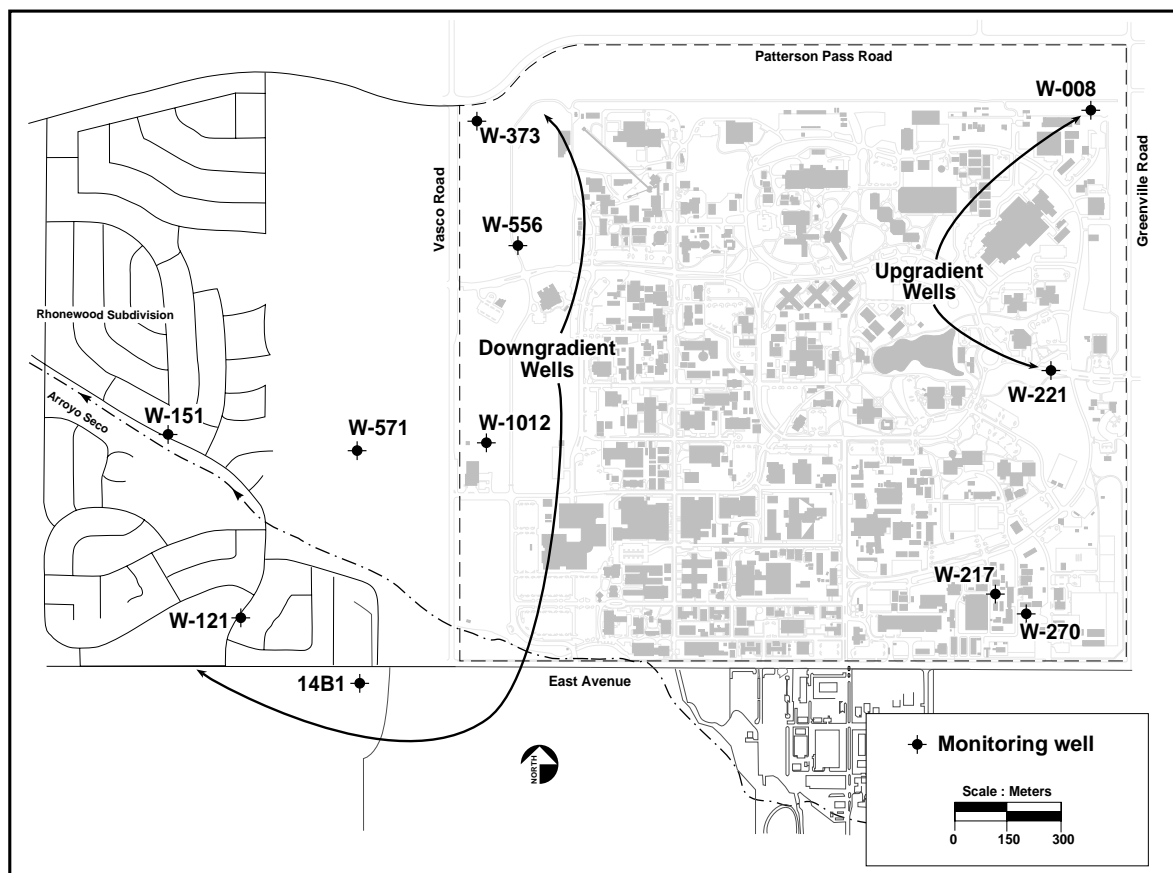


Figure 8-3. Locations of surveillance ground water monitoring wells at the Livermore site, 1996.



These wells were sited to satisfy Resource Conservation and Recovery Act (RCRA) monitoring and California Code of Regulations Title 22 monitoring requirements.

For the Livermore Ground Water Project, the constituents of concern (COCs) are VOCs, primarily trichloroethylene (TCE) and tetrachloroethylene (PCE). **Figure 8-4** shows the isoconcentration contours on total VOCs in HSU 2. The seven operating ground water treatment facilities (TFA, TFB, TFC, TFD, TFE, TFG1, and TF406) removed a total VOC mass of more than 40 kg by treating 470 ML of ground water in 1996 (Hoffman et al. 1997).

The two upgradient wells were sampled and analyzed quarterly in order to obtain sufficient data for statistics; the seven downgradient wells were sampled and analyzed semiannually. Each well was sampled and analyzed for metals and minerals (except for ammonia as nitrogen and total Kjeldahl nitrogen), gross alpha and beta, tritium, and radium and uranium radioisotopes.

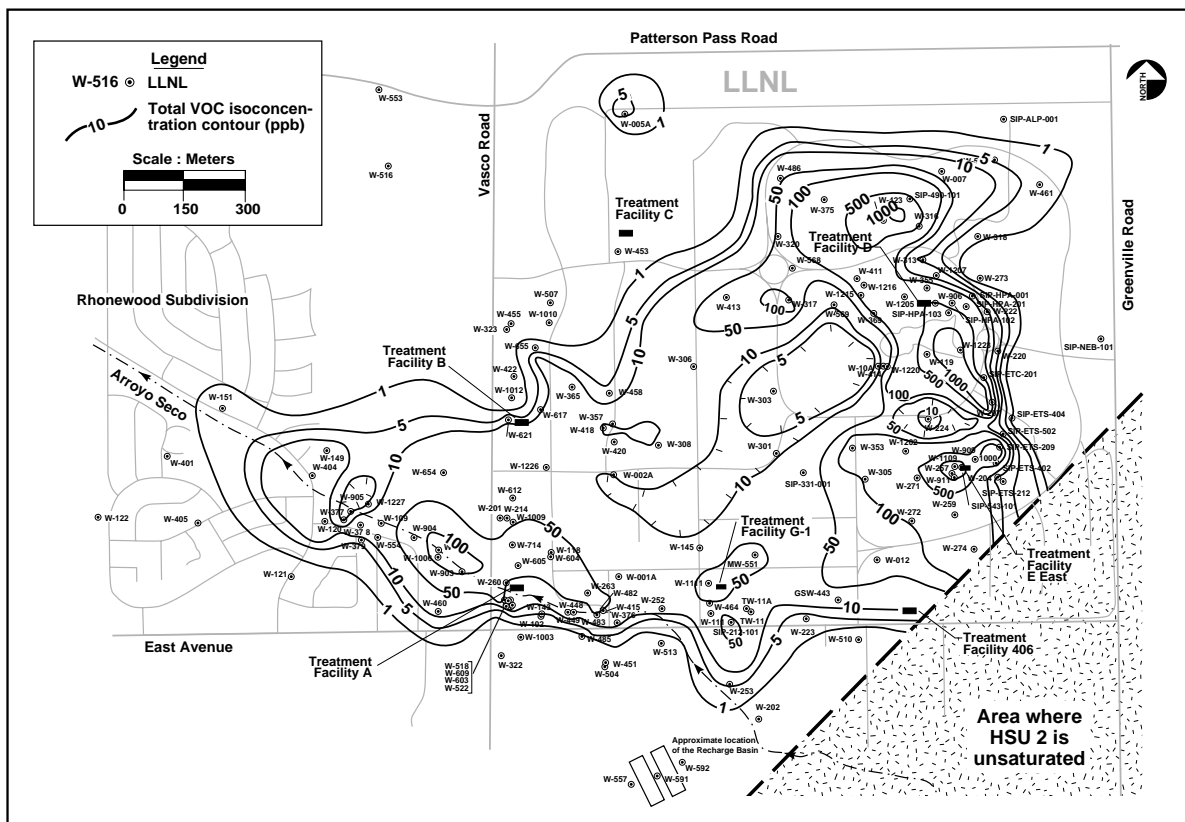


Figure 8-4. Map showing distribution of VOCs for 154 sampling locations in Hydrostratigraphic Unit 2 (HSU2), at Livermore site and vicinity, 1996.



8

Ground Water

Examination of the City of Livermore drinking water wells revealed levels of radioactive radon gas up to 10.7 Bq/L (290 pCi/L). It was therefore decided to add analysis for radon-222 to the list of ground water analytes. Organic compounds, including semivolatile compounds (EPA Method 625) and chlorinated herbicides (EPA Method 615), were monitored during the first 6 months of the year. During the last 6 months of the year, EPA Methods 625, 507, 547, and 632 were used to monitor nitrogen-based and phosphorus-based pesticides and herbicides that are presently being used on site along with semivolatile compounds. **Tables 8-1, 8-2, and 8-3** show the important water quality objectives for organic, inorganic, and radioactive compounds, respectively.

Table 8-1. Water quality objectives for organic compounds of concern, 1996.

Analytes	EPA method	CA or federal MCLs ^(a) (µg/L)	Non-cancer risk (µg/L)	SFBRWQCB ^(b) Basin Plan (µg/L)
Atrazine	507	3.0	3	3
Benzo(a)pyrene	625	0.2	0.002 ^(c)	0.2
Bis(2-ethylhexyl)phthalate	625	4	3 ^(c)	4
Bromacil	507	NA ^(d)	90	NA
2,4-D	615	70	70	70
Dalapon	615	200	200	200
Diazinon	507	14 ^(e)	0.6	NA
Dicamba	615	NA	200	NA
Diethylphthalate	625	NA	5000	NA
Dimethoate	507	140 ^(e)	NA	NA
Diuron	632	NA	10	NA
Glyphosate	547	700	700	700
MCPA	615	NA	11	NA
Metolachlor	507	NA	100	NA
Molinate	507	20	14	20
Propachlor	507	NA	90	NA
Simazine	507	4	4	4
2,4,5-T	615	NA	70	NA
2,4,5-TP	615	50	50	50
Thiobencarb	507	70	140	1

^a Maximum contaminant level.

^b San Francisco Bay Regional Water Quality Control Board.

^c Cancer risk from EPA.

^d NA = Not applicable.

^e California Department of Health Services Action Levels.

**Table 8-2.** Water quality objectives for inorganic compounds of concern, 1996.

Analyte	CA or federal MCL ^(a) (mg/L)	SFBRWQCB ^(b) Basin Plan (mg/L)	EPA health advisory (mg/L)
Aluminum	1	1/0.2	NA
Antimony	0.006	0.006	0.003
Arsenic	0.05	0.05	0.00002
Barium	1	1	2
Beryllium	0.004	0.004	0.000008
Boron	NA ^(c)	0.5/2	0.6
Cadmium	0.005	0.005	0.005
Chloride	250 ^(d)	250	NA
Chromium(VI)	0.05	0.05	0.1
Copper	1 ^(d)	1	NA
Cyanide	0.2	0.2	0.2
Fluoride	1.4–2.4	0.8/1.7	NA
Iron	0.3 ^(d)	0.3	NA
Lead	0.015	0.05	NA
Manganese	0.05 ^(d)	0.05	NA
Mercury	0.002	0.002	0.002
Molybdenum	NA	0.01/0.05	0.035
Nickel	0.1	0.1	0.1
Nitrate (as NO ₃)	45	45	45
Nitrite (as N)	1	1	1
pH	6.5–8.5 ^(d)	6.5	NA
Selenium	0.05	0.05	NA
Silver	0.1 ^(d)	0.05	0.1
Specific conductance (µmho/cm)	900 ^(d)	900	NA
Sulfate	250 ^(d)	250	NA
Total dissolved solids (TDS)	500 ^(d)	500	NA
Thallium	0.002	0.002	0.0004
Vanadium	NA	0.1/1	NA
Zinc	5 ^(d)	5	2

^a Maximum contaminant level, as listed in U.S. Environmental Protection Agency (USEPA) Region IX *Drinking Water Standards and Health Advisories Table*, July 1994.

^b San Francisco Bay Regional Water Quality Control Board.

^c NA = Not applicable.

^d U.S. Environmental Protection Agency (USEPA) and/or California Secondary MCL.



8

Ground Water

Table 8-3. Water quality objectives for radioactive compounds.

Radionuclide	CA or federal MCL ^(a) (Bq/L)	SFBRWQCB ^(b) Basin Plan (Bq/L)	EPA health advisory (Bq/L)
Gross alpha (excluding uranium and radon)	0.56	0.56	0.0056
Gross beta	1.85	1.85	0.4 μ Sv (0.04 mrem)/y
Radium-226	0.185 ^(c)	0.185 ^(c)	0.0074
Radium-228	0.185 ^(c)	0.185 ^(c)	0.0074
Radon	11.1 ^(f)	NA ^(e)	0.056
Tritium	740	740	NA
Uranium-234	0.74 ^(d)	0.74 ^(d)	0.7 μ g/L (total uranium)
Uranium-235	0.74 ^(d)	0.74 ^(d)	0.7 μ g/L (total uranium)
Uranium-238	0.74 ^(d)	0.74 ^(d)	0.7 μ g/L (total uranium)

^a Maximum contaminant level.

^b San Francisco Bay Regional Water Quality Control Board.

^c For both radium-226 and -228.

^d Isotopes of uranium are undifferentiated by the U.S. Environmental Protection Agency (USEPA) guidance documents.

^e NA = Not applicable.

^f Proposed MCL.

All surveillance monitoring analytical detections are presented in Volume 2 of this document (Tables 8-1 through 8-10). These first-year monitoring efforts will establish baseline conditions for future monitoring and establish the presence of any radioactive materials in the ground water at levels of concern to public health or to the environment.

Monitoring Results

Neither cyanide (via EPA Method 335.2), pesticides nor herbicides (via EPA Methods 507, 547, 615, and 632) were detected. However, bis(2-ethylhexyl)phthalate (DEHP), a ubiquitous plasticizer, was detected for the first time in samples collected in downgradient monitoring wells W-571 and W-1012. DEHP concentrations of 19 and 14 μ g/L were found in W-571 ground water samples collected in March and August, respectively, and 21 μ g/L of DEHP was found in a ground water sample collected from W-1012 in March. DEHP was not detected above the reporting limit of 5 μ g/L in the August sample from W-1012. Because W-571 is located in a field in which housing construction began in 1996, sampling was not possible during the third and fourth quarters of 1996 and first quarter of 1997. When sampling of monitoring Well W-571 resumed in June 1997, no phthalates were detected. Another semivolatile compound, diethylphthalate, was detected in downgradient monitoring wells W-373 and W-556 at concentrations of 17 and 15 μ g/L, respectively, in ground water samples collected in



March. However, diethylphthalate was also detected in the method blank sample at a concentration of 18 µg/L, which indicates laboratory contamination. Because of the erratic sequence of detections and known potential contamination problems at the analytical laboratory, the phthalate detections are suspect.

Most of the inorganic compounds, including dissolved trace metals and minerals, are naturally occurring compounds. It should be noted that several minerals—bicarbonate, boron, bromide, chloride, and fluoride—are present at much higher concentrations in the upgradient wells than in the downgradient wells. Bicarbonate concentrations ranged from 230–330 mg/L, boron from 1.8–19 mg/L, bromide from <0.5–1.6 mg/L, chloride from 120–720 mg/L, and fluoride from 0.74–1.3 mg/L in the upgradient wells. Corresponding downgradient concentrations were: bicarbonate 180–260 mg/L, boron from 0.52–1.8 mg/L, bromide from <0.50–0.71 mg/L, chloride from 76–160 mg/L, and fluoride from 0.23–0.95 mg/L. Chapter 3 of the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990) documents the poor water quality in the upgradient portions of the site, especially near Well W-008.

Nitrate was detected at concentrations of 75 and 85 mg/L in March and September, respectively. Both concentrations are above the drinking water MCL of 45 mg/L. Wells surrounding W-1012 are presently being sampled for nitrate.

Nickel was reported at 24 µg/L in the ground water sample collected from upgradient monitoring Wells W-221 in June. In samples collected in June, cadmium was detected at concentrations of 1.5 µg/L in upgradient Well W-008 (in the northeastern corner of LLNL) and at 0.5 µg/L (the reporting limit) in upgradient monitoring Wells W-221. Cadmium was again detected at 1.1 µg/L in the sample collected from Well W-008 in September.

Until 1990, total chromium was found in concentrations greater than 100 µg/L in downgradient monitoring Wells W-373, in the northwestern corner of LLNL. Since then concentrations of both total chromium and chromium(VI) in the ground water have been decreasing. Concentrations of dissolved chromium(VI) decreased to 76 and 56 µg/L, respectively, in samples taken in March and August from this well. Ground water in the area of TFC has been treated since October 1993 (Chapter 7).

None of the ground water samples from surveillance wells had concentrations of radioactivity or radioisotopes that exceeded a drinking water MCL. The highest concentration of tritium found was 11.5 Bq/L (311 pCi/L), which is 1.6% of the MCL for tritium.



8

Ground Water

Off Site

LLNL has monitored tritium in water hydrologically downgradient of LLNL since 1988; tritium is potentially the most mobile contaminant emanating from LLNL in ground water (**Figure 8-5**). Rain and storm water runoff in the Livermore Valley recharges local aquifers and contains small amounts of tritium from natural sources, past atmospheric nuclear weapons tests, and atmospheric emissions from LLNL and Sandia National Laboratories (SNL/California). (See Chapters 5 and 7 for further discussion of air emissions and rain.)

Measurements in water samples collected during the summer of 1996 from 21 wells in the Livermore Valley show tritium levels were very low compared with the 740 Bq/L (20,000 pCi/L) MCL established by the State of California.

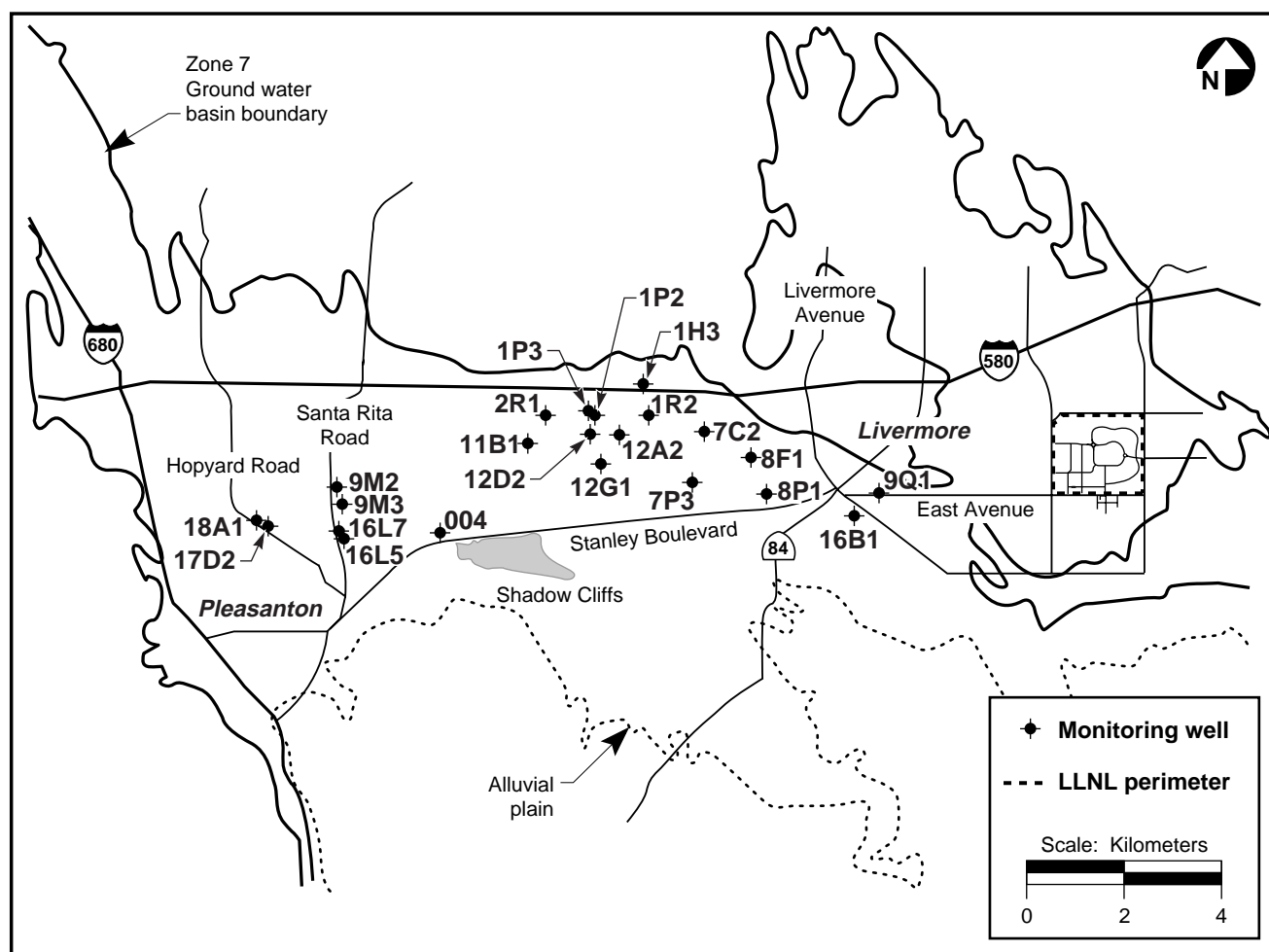


Figure 8-5. Locations of surveillance ground water monitoring wells in the Livermore Valley.



As a further comparison, tritium was measured at < 1.19 to 2.89 Bq/L (0.044 to 78.1 pCi/L) in ground water samples from on-site upgradient monitoring wells and from < 1.66 to 11.5 Bq/L (44.9 to 310.8 pCi/L) in on-site downgradient monitoring wells. As in previous years, the highest tritium activity measured was in a ground water sample from Well 11B1, located about 10 km west of LLNL. The activity in that sample in 1996 was 13.9 Bq/L (377 pCi/L), a decrease of 58% from its measurement of 33.0 Bq/L (893 pCi/L) in 1988. This is a slightly greater decrease than can be accounted for by simple radioactive decay.

Tritium activity has shown a decreasing trend overall in Livermore Valley ground waters downgradient of LLNL. The median activities of tritium in ground water samples from these downgradient wells increased from 3.45 Bq/L (93.2 pCi/L) in 1988 to 4.59 Bq/L (124 pCi/L) in 1989. By 1996, the median activity had dropped to 2.78 Bq/L (75 pCi/L). This decrease in median activity is approximately equal to that expected through radioactive decay of tritium, which has a half-life of 12.3 years.

Surveillance Ground Water Monitoring of Site 300

Surveillance monitoring of ground water at Site 300 requires samples from DOE on-site wells and from private off-site wells. Ground water samples are routinely measured for the following COCs: various elements, primarily metals; a wide range of organic compounds; general radioactivity (gross alpha and gross beta); and tritium activity. Analytical methods for COCs are selected for their sensitivity, that is, methods are chosen that have reporting limits (RLs) at, or below, toxic concentrations. Typically, drinking water maximum contaminant levels (MCLs) for COCs are referred to when selecting EPA methods for ground water analysis. (See Volume 2, Tables 8-11 and 8-12 for a complete list of COCs and the EPA methods, or other standard methods, used to measure COC concentrations in ground water.)

Figure 8-6 shows 31 surveillance and 2 compliance ground water sampling locations, which utilize a total of 24 wells and 3 springs. The primary water-bearing strata at Site 300 are the Neroly Formation upper and lower blue sandstones (Tnbs₁ and Tnbs₂) and the underlying Cierbo Formation (Tmss) (see **Figure 8-2**). At some well locations there are as many as three distinct water-bearing zones separated by aquitards. Although most of the sampling locations at Site 300 take ground water from the shallowest water-bearing zone, four surveillance wells (K1-01, K1-02, K2-01, and K2-02) are fitted with a total of 10 Barcad devices that provide water samples from deeper water-bearing zones at those locations, one Barcad for each water-bearing zone. Nitrogen gas is admitted under pressure to the Barcad sampling devices to extract ground water for chemical analysis.



8

Ground Water

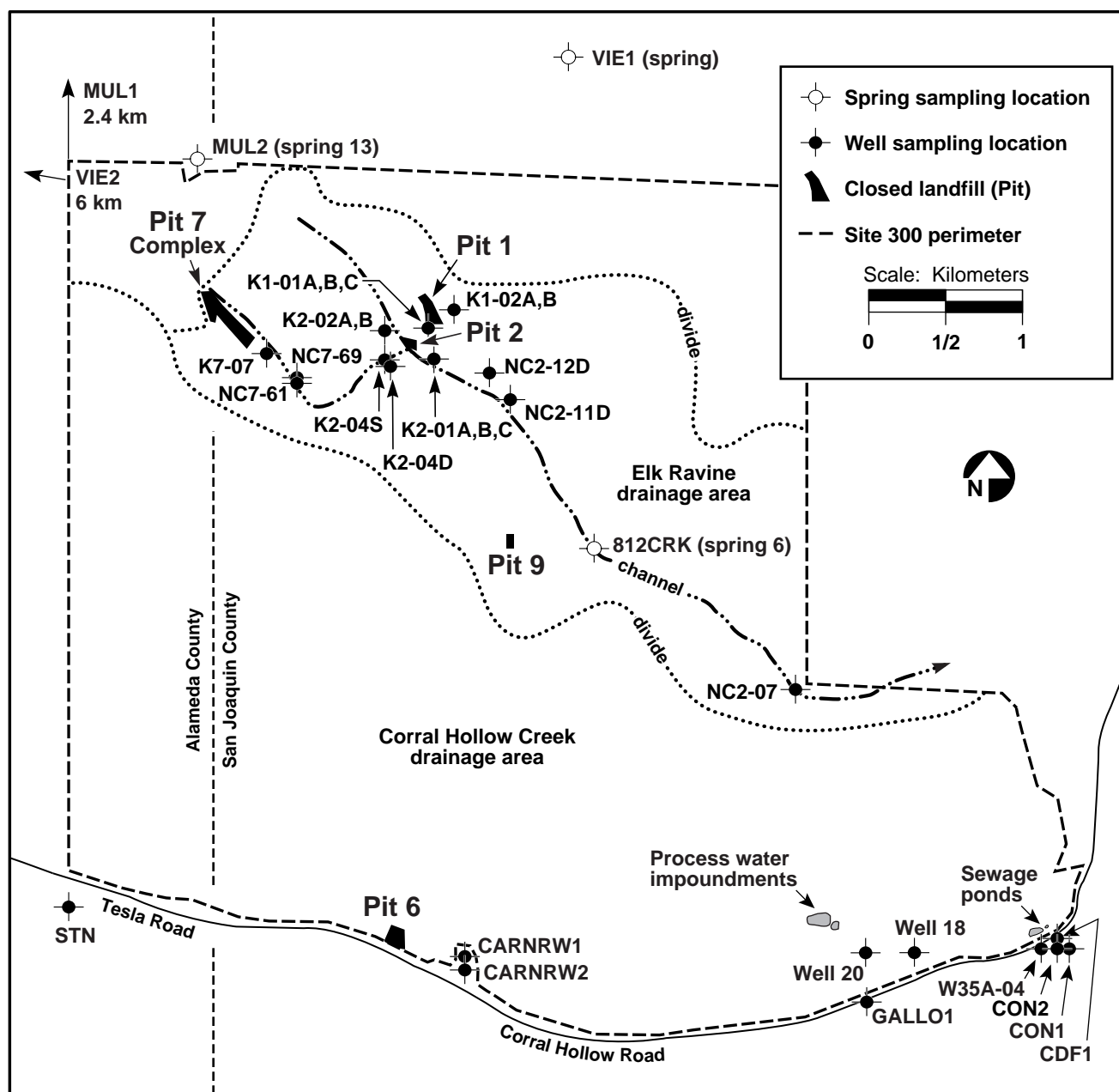


Figure 8-6. Locations of surveillance ground water wells and springs, Site 300, 1996.

Barcad samplers are identified according to depth in **Figure 8-6** by the capital letters A, B, C, separated by commas at the end of a well's code name. For example, Barcad A always samples the deepest water-bearing zone. Barcads K1-01C and K1-02B at Pit 1 monitor the shallowest water-bearing zone for compliance purposes.



Of the 31 surveillance sampling locations, 12 are off site. Three, including spring MUL2 and spring VIE1, are north of Site 300, where the Altamont hills slope down to the San Joaquin Valley. Well VIE2 lies 6 km west of Site 300 in the upper reaches of the Livermore Valley watershed. The remaining eight off-site surveillance locations are wells located south of Site 300 in the Corral Hollow Creek drainage area.

Twelve on-site surveillance wells are used to monitor three inactive landfills (closed pits). Six wells monitor Pit 6 (**Figure 8-7**). Four wells monitor Pit 9 (**Figure 8-8**). Six Barcads in three wells are used to monitor Pit 2 (K2-01A and B, K2-02A and B, and K1-01A and B in **Figure 8-9**). Nine on-site surveillance wells and one spring (812CRK) are located along the system of fault-marked ravines and arroyos that comprise the Elk Ravine drainage area (**Figure 8-6**). Surveillance monitoring includes two on-site water production wells, Well 18 and Well 20 (**Figure 8-6**). Well 20 provides potable water to Site 300. Well 18 is maintained as a standby supply well.

Brief descriptions of the Site 300 surveillance areas and their monitoring wells are given below, together with ground water monitoring results for 1996. Detailed descriptions of Site 300 geology, hydrogeology, and the nature and extent of ground water contamination there can be found in the Final SWRI Report (Webster-Scholten 1994).

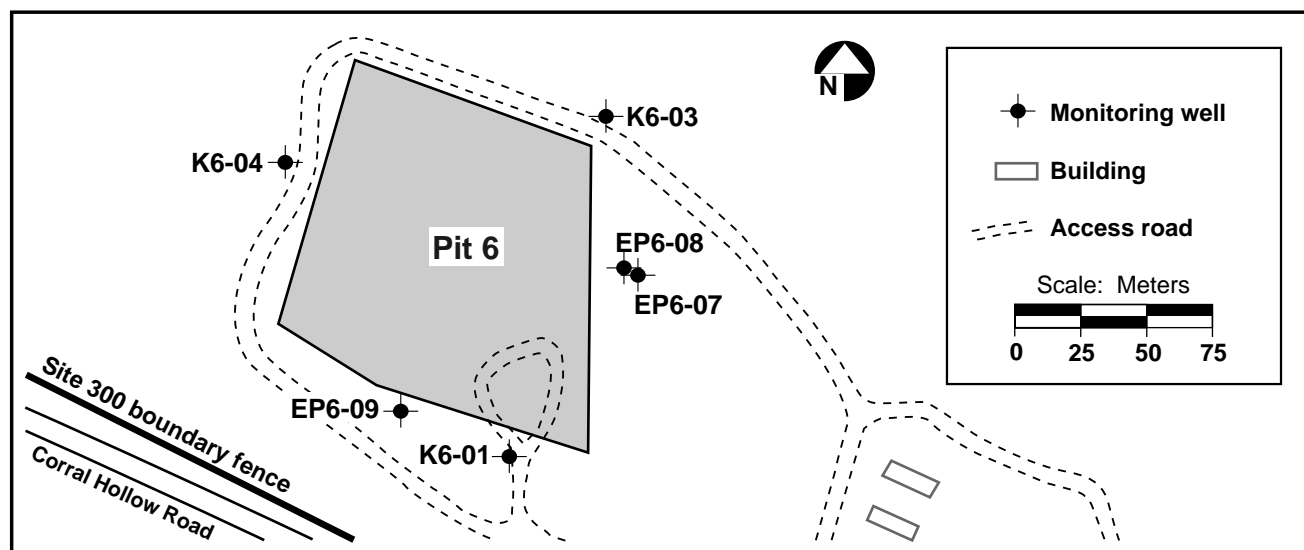


Figure 8-7. Locations of surveillance ground water monitoring wells, Pit 6, 1996.



8

Ground Water

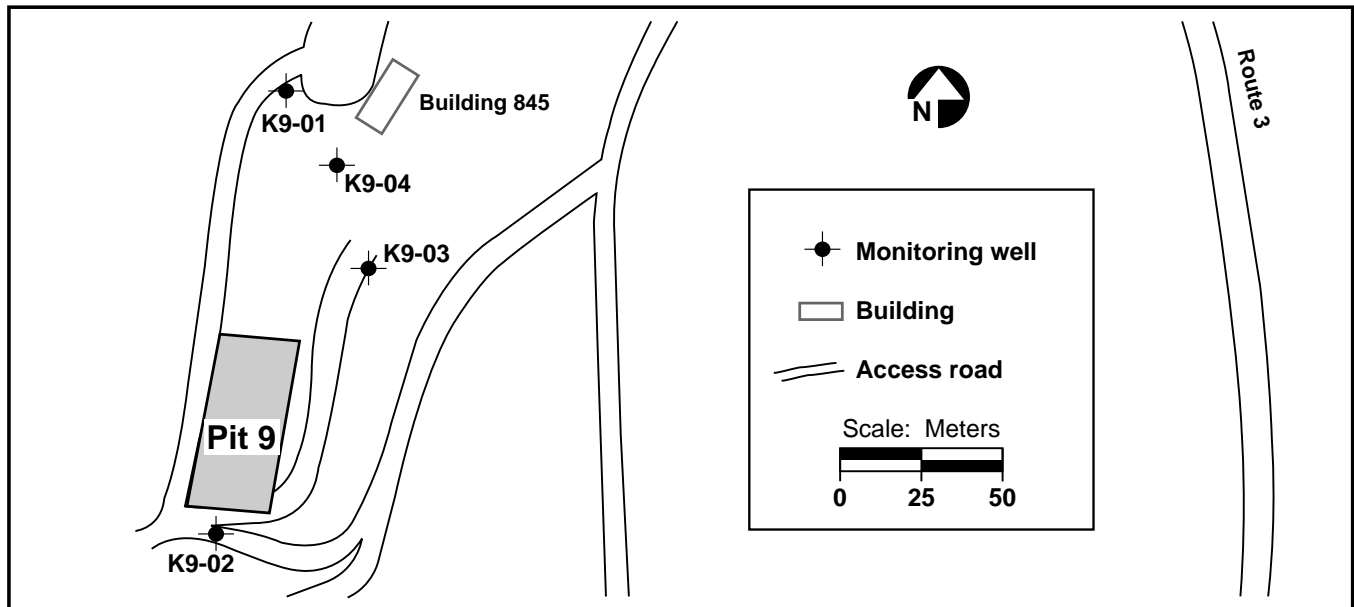


Figure 8-8. Locations of surveillance ground water monitoring wells, Pit 9, 1996.

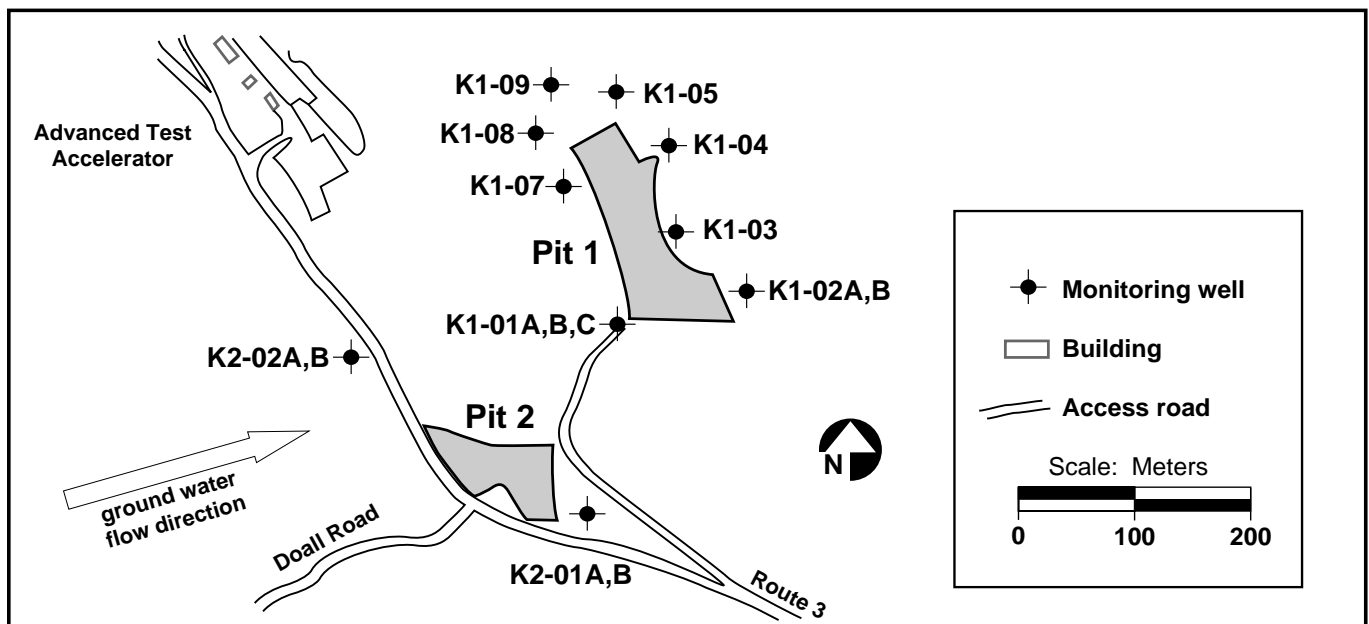


Figure 8-9. Locations of compliance ground water monitoring wells, Pit 1 (K1-01C, -07, -02B, -03, -04, -05, -08, and -09) and Pit 2 surveillance wells (K1-01A and B, K1-02A, K2-01A and B, and K2-02A and B), 1996.



Pit 6

The unlined, closed, Pit 6 landfill lies at an average elevation of 210 m above sea level and covers an area of about 1 hectare adjacent to the southern boundary of Site 300 (**Figures 8-6 and 8-7**). From 1964 to 1973, about 1529 cubic meters (2000 cubic yards) of solid waste were buried in 9 separate trenches within the landfill. Three larger trenches contain about 1300 cubic meters (1700 cubic yards) of solid waste that includes empty drums, glove boxes, lumber, ducting, and capacitors. Six smaller trenches contain about 229 cubic meters (300 cubic yards) of biomedical waste, including animal carcasses and animal waste. A relatively small shallow plume of ground water containing TCE extends about 150 m eastward from Pit 6, parallel to Corral Hollow Road (see Chapter 2, **Figure 2-2**).

Pit 6 is sited in Quaternary terrace deposits (Qt; **Figure 8-2**) above and north of the Corral Hollow Creek flood plain. Tertiary Neroly sedimentary rocks (Tnbs₁; **Figure 8-2**) lie beneath the terrace deposits. Surface runoff from the pit area is southward to Corral Hollow Creek. Ground water flows southward beneath the pit, following the south-dipping sedimentary rocks. However, flow abruptly turns eastward beneath the southern margin of the landfill where movements along the Carnegie Fault have brought vertically dipping strata on the south into contact with the gently southward dipping strata to the north. A deposit of terrace gravel in a trough within the vertically dipping strata immediately south of the landfill acts as a channel for the ground water to flow eastward after it passes beneath Pit 6 (Webster-Scholten 1994).

Currently, six wells are used for surveillance monitoring of ground water in the vicinity of Pit 6 (**Figure 8-7**). With respect to the landfill and ground water flow, Well K6-03 is hydrologically upgradient, Wells K6-04, EP6-07, and EP6-08 are cross-gradient, and Wells EP6-09 and K6-01 are downgradient from Pit 6.

Ground water samples were collected twice during 1996 from the six monitoring wells. The samples were analyzed for various elements, mostly metals; volatile organic compounds, including pesticides; explosives compounds; general radioactivity (gross alpha and gross beta); and tritium (³H) activity.

Data for COCs from the Pit 6 surveillance monitoring wells are presented for each of the six monitoring wells in Volume 2, Tables 8-13 through 8-18. Metals were generally not detected above RLs in Pit 6 well samples. Of the elements detected, none exceeded an MCL. Arsenic, barium, and selenium were detected at concentrations consistent with natural concentrations in the area ground water (Webster-Scholten 1994). Molybdenum, mercury, and silver were detected at extremely low concentrations. They do not represent the ground water and were probably introduced at the analytical laboratory.



8

Ground Water

TCE was the only organic compound detected above its 5 µg/L MCL in ground water from Pit 6. It was detected in Well EP6-09 at 14 µg/L (see Volume 2, Table 8-18). The concentration of TCE in the ground water sampled at Well EP6-09 was down 50% from the µg/L value (28 µg/L) in 1995. This surveillance well specifically monitors the shallow plume of TCE-bearing ground water that extends a short distance eastward from Pit 6. The TCE plume is fully characterized and assessed in the Final SWRI Report (Webster-Scholten 1994). Conservative modeling indicates little or no risk to the environment from this slowly moving plume.

All radioactivity measurements during 1996 for gross alpha, gross beta, and tritium were below their respective MCLs in drinking water. Radioactivity of the ground water in the vicinity of Pit 6 was indistinguishable from natural background.

Pit 2

The unlined, closed, Pit 2 landfill primarily contains waste gravels and debris from experiments conducted at the Building 801 and 802 firing tables. The gravels contain debris from hydrodynamic tests of explosive devices. The waste material contains depleted uranium, or “D-38,” a form of uranium consisting of the nonfissionable ²³⁸U isotope. Trace amounts of beryllium, thorium, and tritium may also be present. The closed Pit 2 landfill lies in the upper portion of Elk Ravine, about 320 m above sea level (**Figures 8-6 and 8-9**). Surface runoff from the Pit 2 area is southerly into Elk Ravine. Subsurface water flow beneath the area is east-northeast, following the inclination (dip) of the underlying Miocene Tnbs₁ and Tmss sedimentary strata (**Figure 8-2**).

Multiple completion Well K1-01, which is downgradient of Pit 2, contains 3 Barcad devices (A, B, and C, see **Figure 8-9**) that sample three separate water-bearing intervals within the claystones and sandstones of the underlying Cierbo Formation (Tmss). (Barcad K1-01C, which taps the shallowest water-bearing zone, also serves as one of two upgradient ground water monitoring points for the Pit 1 landfill to the northeast of Pit 2.) Multiple completion Wells K2-01 and K2-02 are hydrologically cross-gradient from Pit 2, but water samples from them are presumed to represent the upgradient ground water. Barcads K2-01A, K2-02A, and K2-02B are completed in Tmss. Barcad K2-01B is completed in Tnbs₁.

For surveillance purposes at Pit 2, ground water samples from the three monitoring wells were taken twice (semiannually) during 1996. The samples were analyzed for various elements, mostly metals; volatile organic compounds; explosives compounds; general radioactivity (gross alpha and gross beta); and tritium (³H) activity.

Constituents-of-concern data for the seven Pit 2 surveillance monitoring well Barcads are presented in Volume 2, Tables 8-19 through 8-25. Metals were generally not detected above reporting limits in Pit 2 well samples. None exceeded a drinking water MCL.



The arsenic and barium concentrations measured are within the range of natural background concentrations found in ground waters elsewhere at Site 300 and throughout the Altamont Hills (Webster-Scholten 1994).

The radioactivity and radioisotope measurements show only low background activities for gross alpha and gross beta. Tritium activities were at low background levels in all water bearing zones near Pit 2 except for the shallow zone sampled by Barcad K2-01B. Although the maximum tritium activity measured in samples from Barcad K2-01B during 1996 was only 10 Bq/L, it is elevated relative to the activities measured in samples taken from the other Barcads and it is above background tritium activity in ground waters at Site 300 (1–2 Bq/L). This relatively elevated activity is associated with a plume of tritium-bearing water that originates beneath the Building 850 firing table, about 1 km upgradient (west) from Pit 2 (see Elk Ravine Drainage Section) (Webster-Scholten 1994; Taffet et al. 1996). The plume appears to be confined to the Neroly formation lower blue sandstone (Tnbs₁) in the vicinity of Pit 2. The incursion of this tritium-bearing water into the Pit 2 area is also recorded in Barcad K1-02B ground water samples. That Barcad is a downgradient monitoring point for RCRA-closed landfill Pit 1. No measurements made on monitoring well samples suggest that any COCs were released from Pit 2 to ground water during 1996.

Pit 9

The inactive, closed, Pit 9 landfill is centrally located within Site 300 and lies at an average elevation of 340 m above sea level. Similar to Pit 2, the closed Pit 9 landfill contains waste gravels and explosive experiment debris from the Building 845 firing table. Surface runoff from Pit 9 is northward into Elk Ravine. Subsurface ground water flow is north-northeast in the lower blue sandstone of the Neroly Formation (Tnbs₁).

Figure 8-8 shows the locations of the four surveillance wells used to monitor the ground water in the vicinity of Pit 9. Monitoring Well K9-02 is hydrologically upgradient from Pit 9. Wells K9-01, K9-03, and K9-04 are downgradient.

Well K9-02 is completed at the contact between Tnbs₁ and Tmss. Wells K9-01, K9-03, and K9-04 are completed and screened in Tmss, just below its contact with Tnbs₁.

For surveillance purposes, Pit 9 monitoring Well K9-01, K9-02, and K9-03 were sampled once during 1996. The ground water samples were analyzed for various elements, mostly metals; nitrate; explosives compounds; volatile organic compounds; general radioactivity (gross alpha and gross beta); and tritium (³H) activity.

Constituents of concern data for the four Pit 9 surveillance monitoring wells are presented in Volume 2, Table 8-26. No measurement exceeded an MCL for drinking water. No evidence for a release of any measured COC from Pit 9 was uncovered. All



8

Ground Water

metals, explosives compounds, organic compounds, and radioisotopes were either not detected, or were indistinguishable from natural background concentrations.

Elk Ravine Drainage Area

The Elk Ravine drainage area includes most of northern Site 300, the area between the drainage divides shown in **Figure 8-6**. Surface runoff from closed landfills within the Elk Ravine drainage area (Pits 1, 2, 3, 4, 5, 7, and 9) is collected in arroyos. With sufficient seasonal rainfall, unconfined ground water can flow southeast on and within the Quaternary alluvial valley-fill deposits (Qal) that floor the Pit 7 Complex Valley. Surface runoff from the Pit 7 Complex Valley (containing the most elevated landfills) can flow southeast to Doall Road, where it is deflected northeastward into Doall Ravine by a landslide deposit (Qls). At the northeastern end of Doall Ravine, this runoff combines with channeled runoff from the Advanced Test Accelerator (ATA) Building 865 area. From this confluence point, the arroyo trends southeasterly within Elk Ravine. Near Well NC2-07, channeled runoff turns easterly, away from the trend of the Elk Ravine fault, and flows off site for approximately 2 km to its confluence with Corral Hollow Creek. Except for Doall Ravine, the arroyos and valley-fill deposits traverse and follow faults, especially the extensive Elk Ravine Fault, that may provide pathways to the underlying ground water. Thus, ground waters from wells that lie within the Elk Ravine drainage area are monitored for COCs. The monitored wells are (from highest to lowest elevation) K7-07, NC7-61, NC7-69, K2-04D, K2-04S, K2-01C, NC2-12D, NC2-11D, and NC2-07. The 812CRK sampling location is a natural spring (also known as Spring 6). It is located in the main Elk Ravine arroyo on the Elk Ravine Fault. Individual well locations are discussed below.

Well K7-07 is located in the Pit 7 Complex Valley. It is a shallow well completed in both Tnbs₁ and Qal. This well is downgradient from landfill Pits 3, 4, 5, and 7, with respect to unconfined flow in the valley-fill deposits (Qal) and to surface runoff. Wells NC7-61 and NC7-69 are completed in separate water-bearing zones beneath the upper reaches of Doall Ravine. Well NC7-61 is completed in Tnbs₁ (shallower zone), and Well NC7-69 is completed in Tmss (deeper zone). Wells K2-04D and K2-04S and Barcad K2-01C are located near the join between Elk Ravine and Doall Ravine. They are all completed in Tnbs₁. Wells NC2-12D and NC2-11D are located in Elk Ravine below its join with Doall Ravine. Well NC2-11D is completed at the contact between Tnbs₁ and Tmss. NC2-07 is the furthest downstream surveillance well in the Elk Ravine drainage area. It is completed in Tnbs₁.

For surveillance purposes, ground water samples were taken at six-month intervals (semiannually) during 1996 from monitoring wells in Elk Ravine and from the 812CRK spring. The samples were analyzed for various elements, mostly metals; explosives compounds; volatile organic compounds; general radioactivity (gross alpha and gross beta); and tritium (³H) activity.



Surveillance analytical data for the ground water samples obtained during 1996 from monitoring wells in the Elk Ravine drainage area are given in Volume 2, Tables 8-27 through 8-36. Generally, no VOCs or HE compounds were detected. Arsenic, barium, molybdenum, selenium, and vanadium were detected at low concentrations consistent with natural sources for these elements in the rocks at Site 300. Except for tritium activity, gross alpha and beta activities were low and were indistinguishable from natural background. Tritium activity was above background in many of the ground water samples. Anomalous measurements for individual well samples are discussed below.

Well K7-07

Semiannual samples gave tritium activities of 238 Bq/L and 139 Bq/L, considerably above tritium activity background (1–2 Bq/L). These results were expected. Well K7-07 lies within a known plume of tritium-bearing water.

LLNL remedial investigators have previously concluded that tritium, as tritiated water (HTO), is released occasionally from soil moisture in landfills and beneath the firing table at Building 150. Tritiated water is released from Pit 3 and Pit 5 during wetter-than-normal winters when ground water rises and contacts firing table wastes contained in these two unlined landfills. A major release of HTO occurred during the unusually wet winter of 1982–83 (Webster-Scholten 1994), and additional minor releases occurred during the wet winters of 1992–93 and 1994–95 (Taffet et al. 1996). HTO is also transported to ground water beneath the Building 150 firing table gravels by percolating water from rain and from dust-control spraying (Taffet et al. 1996). The configuration of the tritium-bearing ground water plume at Site 300, updated for 1996, is shown in **Figure 8-10**. The HTO plume is shallow and appears to be confined to the Neroly lower blue sandstone (Tnbs₁).

Wells NC7-61 and NC7-69

Well NC7-61 samples ground water from within the tritium plume near its source beneath the Building 850 firing table (**Figure 8-10**). The semiannual ground water samples from Well NC7-61 had elevated tritium activities of 6316 Bq/L and 6543 Bq/L. The mean of the two activities, 6430 Bq/L, is 7.8% lower than the 1995 mean, 6975 Bq/L. The decay of tritium (12.3 year half-life) accounts for 5.5% of this decrease over the one-year period. The remaining 2.3% decrease can be attributed to diffusion of HTO and downgradient movement of the plume. As in previous years, tritium activity in the underlying Cierbo Formation (Tmss) was very low, less than 1 Bq/L, as measured in the ground water samples from Well NC7-69. The marked difference in tritium activity between ground water samples from these two wells demonstrates that the HTO plume is confined to the shallow Neroly lower blue sandstone (Tnbs₁) in this area.

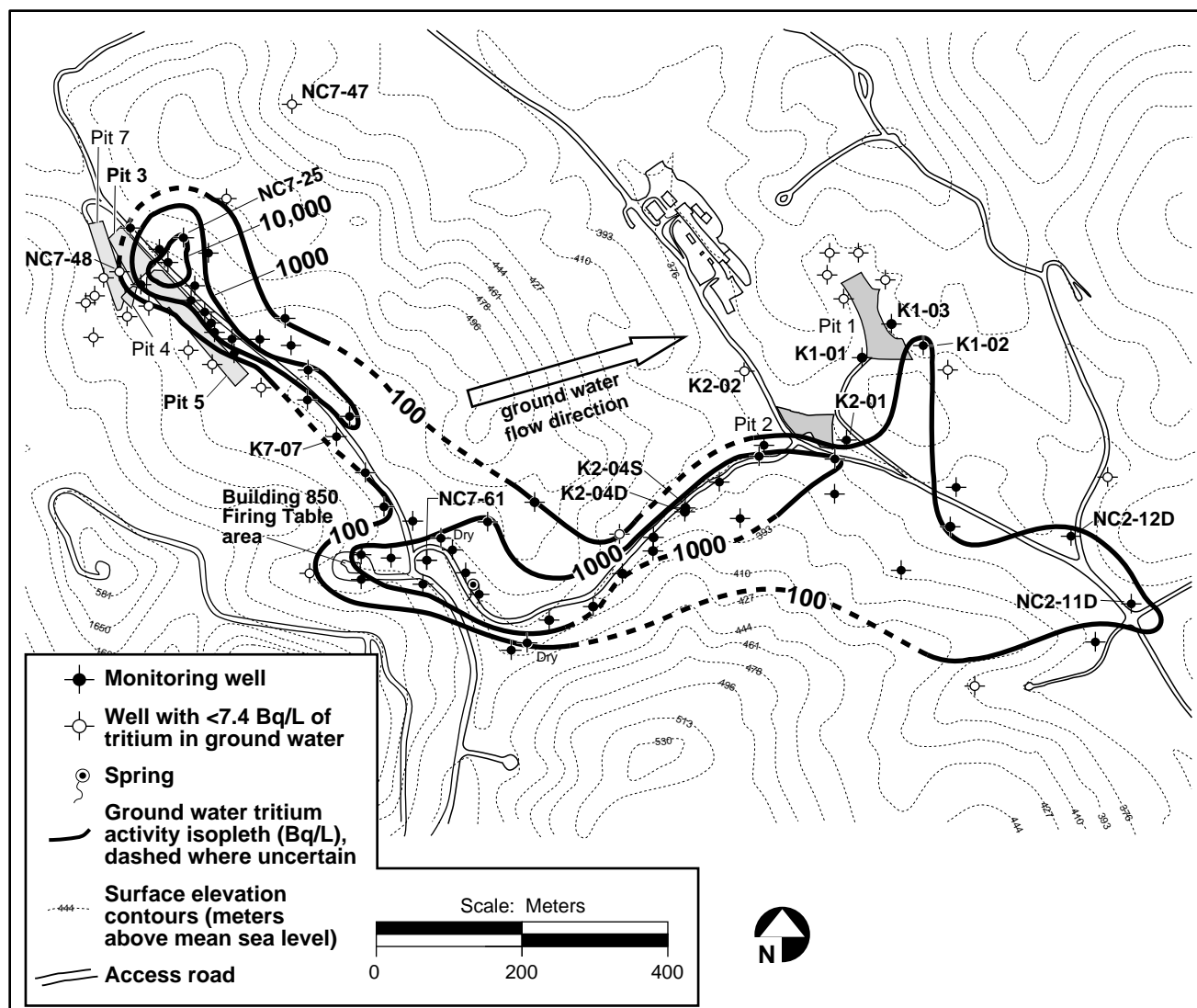


Figure 8-10. Map showing distribution of tritiated ground water extending from the Pit 7 Complex valley to Doall Ravine and Elk Ravine, 1996.

Wells K2-04D, K2-04S, and K2-01C

One antimony measurement (10 $\mu\text{g/L}$ in one ground water sample from monitoring Well K2-04D) exceeded the 6 $\mu\text{g/L}$ drinking water MCL for antimony. However, the detection is questionable, because analysis of a duplicate quality control ground water sample taken from this well gave a nondetection for antimony (< 5 $\mu\text{g/L}$).

Elevated tritium activity relative to background was measured in semiannual ground water samples from all three surveillance wells. These wells also monitor the plume of tritium-bearing ground water that extends from the Pit 7 Complex Valley through Doall Ravine into Elk Ravine (**Figure 8-10**). The 1996 mean tritium activity for Well K2-04D,



277 Bq/L, is 49% lower than the 540 Bq/L mean activity for 1995. The 1996 mean tritium activity for Well K2-04S, 1256 Bq/L, is approximately equal to the 1227 Bq/L mean activity for 1995. The 1996 mean tritium activity for the Well K2-01C samples, 384 Bq/L, is 70% higher than the 227 Bq/L mean for 1995. The upgradient decrease and down-gradient increase in tritium activity reflects continued eastward advection of the HTO plume.

Wells NC2-11D and NC2-12D

Elevated tritium activity relative to background was measured in semiannual ground water samples from both of these surveillance wells. These wells are situated near the leading edge of the tritium-bearing ground water that is moving slowly eastward in the Neroly lower blue sandstone (Tnbs₁) beneath Elk Ravine (**Figure 8-10**). The mean tritium activity for Well NC2-11D, 100 Bq/L, is slightly higher than the 88 Bq/L mean for 1995, and the 216 Bq/L mean for Well NC2-12D is 35% higher than the 160 Bq/L mean for 1995. These increasing activities reflect continuing downgradient movement (advection) of the tritium plume.

812CRK (Spring 6) and Well NC2-07

Detections of arsenic, barium, and vanadium at these locations far below MCLs and near detection limits are consistent with natural sources in the rocks. A trace of mercury in the second ground water sample taken from Well NC2-07 during 1996 is not characteristic of the ground water there. Traces of mercury were also detected in a batch of ground water samples taken from other distant unrelated wells. Most likely, the mercury was introduced at the analytical laboratory. Gross alpha and gross beta activities are low at the two locations and cannot be distinguished from background activities. Tritium activity at the two locations is also very low. These sampling locations are distant from the slowly moving tritium plume beneath Elk Ravine, but they will eventually detect its arrival.

Wells 18 and 20

Well 20 supplied potable water at Site 300 during 1996, while Well 18 was maintained as a standby water supply well. The wells are located in the southeastern part of the site (**Figure 8-6**). Both are deep, high-production water wells that are completed in the Neroly Formation lower blue sandstone (Tnbs₁). The Well 18 completion zone extends upwards into a fine-grained aquitard (Tnsc₁) in the Neroly Formation that separates Tnbs₁ from the overlying upper blue sandstone (Tnbs₂). Either well can produce up to 1500 L/min.

For surveillance purposes, ground water samples were taken at three-month intervals (quarterly) from these two on-site supply wells. Water samples from Well 20 were analyzed for various elements, mostly metals; nitrate; explosives compounds, volatile



8

Ground Water

organic compounds; general radioactivity (gross alpha and gross beta); and tritium (^3H). Well 18 water samples were analyzed for volatile organic compounds; general radioactivity (gross alpha and gross beta); and tritium (^3H).

Surveillance analytical data for the two on-site potable water supply wells are presented in Volume 2, Tables 8-37 and 8-38. No metals of concern were detected in Well 20 during 1996, except molybdenum at 34 ppb in the fourth quarter water sample. Like mercury, molybdenum appeared suddenly during the fourth quarter in trace amounts near the detection limit in several samples from wells distant from each other. Because the affected well samples were from widely separated ground waters, traces of molybdenum, like mercury (and probably silver), were probably introduced at the analytical laboratory during sample processing.

A clear instance of sample contamination occurred during 1996 when lead was unexpectedly measured in 19 well water samples. After LLNL questioned the results, the analytical laboratory discovered lead in their sample preparation equipment and removed it. The wells were sampled again and analyzed for lead. None was detected. The causes of some anomalous mercury, molybdenum, and silver detections could not, unfortunately, be determined with such certainty. It is suspected that routine cleaning of sample preparation and measurement equipment at the analytical laboratory removed evidence of contamination before LLNL's inquiries began.

Gross alpha, gross beta, and tritium activities in water samples from both production wells are very low and are indistinguishable from natural background activities.

Off-Site Supply Wells

For surveillance purposes during 1996, ground water samples were obtained from twelve off-site locations. Eleven of these locations are adjacent to Site 300. A distant well, VIE2, located at a private residence 6 km west of Site 300, is typical of clean water supply wells in the Altamont Hills. One cattle well, MUL1, and two cattle springs, MUL2 and VIE1, are adjacent to Site 300 on the north. Eight wells, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STN, and W-35A-04, are adjacent to the site on the south (**Figure 8-6**). W-35A-04 is a well installed by LLNL for monitoring only. Wells CARNRW2, GALLO1, and STN supply some water for human consumption. Well CDF1 is owned by the California Department of Forestry and supplies water for fire fighting. The remaining wells are used to water cattle or are used for irrigation.

Ground water samples were taken quarterly during 1996 at six off-site well locations. Of these, CARNRW1 and CON2 samples were analyzed only for volatile organic compounds, while CARNRW2, CDF1, CON1, and GALLO1 samples were analyzed for various elements, mostly metals; general parameters; explosives compounds; volatile organic compounds; inorganic compounds; general radioactivity (gross alpha and gross



beta); and tritium (^3H) activity. Six off-site locations—MUL1, MUL2, STN, VIE1, VIE2, and W-35A-04—were sampled once (annually) during 1996 for various elements, mostly metals; nitrate; volatile organic compounds; explosives compounds; general radioactivity (gross alpha and gross beta); and tritium (^3H) activity. In addition to the analyses listed above, uranium isotope activities were determined for the MUL1 and STN ground water samples.

Surveillance analytical data for the 12 off-site water supply locations are presented in Volume 2, Tables 8-39 to 8-45. Arsenic and barium are widely detected at these locations, but their concentrations are below MCLs and are consistent with natural sources in the rocks. A few scattered detections of molybdenum, selenium, copper, lead, and zinc are observed at concentrations below MCLs.

Low concentrations of trihalomethanes (THMs) are detected in water samples from the W35A-04 monitoring well. The THMs were caused by chlorination of the well about one month before the annual surveillance sample was taken.

The concentration of TCE was near the reporting detection limit of $0.2\text{ }\mu\text{g/L}$ in the ground water samples taken from the GALLO1 surveillance well during 1996. The GALLO1 well is hydrologically upgradient from the nearest TCE contamination at Site 300, in the General Services Area (GSA; **Figure 2-2**, Chapter 2). LLNL remedial investigators concluded that the low concentration of TCE in the GALLO1 well water was probably due to a localized surface spill on the property, possibly from solvents used on a pump truck or another vehicle used to service the private well (Webster-Scholten 1994). All radioactivity and tritium activities in ground water samples from the off-site surveillance wells are low and are indistinguishable from natural background activities in the Site 300 area.

Compliance Ground Water Monitoring at Site 300

Little flexibility is available to LLNL for compliance monitoring of ground water at Site 300, where requirements are specified in Waste Discharge Requirement (WDR) Orders, issued by the California Central Valley Regional Water Quality Control Board (CVRWQCB), and in post-RCRA-closure monitoring and reporting plans approved by the California EPA Department of Toxic Substances Control (DTSC). The WDRs and post-closure plans specify the wells to be monitored, the COCs to be measured, measurement frequency, analytical methodology, and the frequency and form of required reports.

Ground water compliance monitoring programs are carried out at Site 300 in response to LLNL Site 300 Resource Conservation and Recovery Act (RCRA) Closure and Post-



8

Ground Water

Closure Plans for Landfill Pits 1 and 7 and WDR Order Nos. 93-100 and 96-248 (amending WDR 85-188). Compliance monitoring and reporting allow LLNL to evaluate operations of closed RCRA Landfill Pits 1 and 7, the Explosives Process Area Class II surface impoundments, and the sewage evaporation and percolation ponds and assure that they are consistent with regulatory requirements. WDR Order No. 93-100 and the post-closure monitoring plan developed within the RCRA Closure and Post-Closure Plans establish the basis for the compliance monitoring network around Pits 1 and 7. Volume 2, Tables 8-46 to 8-49 list Pit 1 and 7 data pertaining to WDR 93-100 and post-closure monitoring. WDR Order No. 96-248 establishes the basis for compliance monitoring of the surface impoundments and sewage ponds. These monitoring programs include quarterly and semiannual monitoring of the ground water wells in each monitoring network, monitoring of various influent streams to the surface impoundments and the sewage ponds, semiannual monitoring, and quarterly visual observations of the sewage ponds. Each compliance monitoring network requires quarterly and annual self-monitoring reporting. Volume 2, Table 8-50 lists constituents of concern that show statistical evidence of having been released to ground water.

Landfill Pits 1 and 7

The Compliance Monitoring Program for Pits 1 and 7 includes ground water sampling and analysis, visual inspections, elevation surveys, and reporting of work performed. The work is specified in monitoring plans that accompany WDR 93-100, Revision 1, (CVRWQCB 1993, 1996), and the RCRA Closure and Post-Closure Plan (Rogers/Pacific Corporation, 1990). Samples of ground water are obtained quarterly from monitoring wells upgradient and downgradient from the two landfills. The samples are analyzed for COCs that may occur in the wastes buried in the unlined landfills. The wastes are mostly gravels from firing tables at Site 300 that contain debris from explosive experiments. In order to maintain the physical integrity of the two landfills, LLNL technical staff visually inspect them at least once a quarter and after major rainstorms. Each year, LLNL hires a Professional Engineer to inspect the two landfills and to provide a written report of findings. LLNL surveyors annually measure the elevations of fixed markers on the two landfill caps. The measurements are used to locate any settling that could adversely affect the integrity of the caps.

Brief descriptions of the compliance areas and their associated monitoring wells follow. More extensive descriptions can be found in the Final SWRI Report (Webster-Scholten 1994) and Addendum (Taffet et al. 1996).

Pit 1 Area

Figure 8-9 shows the RCRA-closed Pit 1 landfill and the eight compliance wells used to monitor the ground water in the vicinity of the inactive landfill. Pit 1 lies in the upper part of the Elk Ravine drainage area at an average elevation of 330 m above sea level.



The RCRA cap constructed on Pit 1 in 1992 includes a layer of impermeable clay to prevent rainwater infiltration. A water-diversion channel made of concrete surrounds the landfill. Its purpose is to reduce local ground water recharge by collecting runoff from the cap and the surrounding area. The outfall of the diversion channel is at the southwest corner of Pit 1, where surface runoff flows to Elk Ravine.

Ground water flows in an east-northeast direction beneath Pit 1, following the dip of the underlying sedimentary rocks. The eight Pit 1 compliance monitoring wells are screened in the shallowest water-bearing zone, either in the Neroly Formation lower blue sandstone (Tnbs₁), or beneath Tnbs₁ in the Cierbo Formation (Tmss; **Figure 8-2**).

With respect to Pit 1 and the direction of ground water flow, Wells K1-01C and K1-07 are hydrologically upgradient, Wells K1-02B, K1-03, K1-04, and K1-05 are downgradient, and K1-08 and K1-09 are cross-gradient.

For compliance monitoring purposes, samples of ground water were taken quarterly from Pit 1 monitoring wells and were analyzed for COCs. Measurements were made for various elements, mostly metals; general radioactivity (gross alpha and gross beta); the radioisotopes tritium (³H), radium (²²⁶Ra), uranium (²³⁴U, ²³⁵U, and ²³⁸U), and thorium (²²⁸Th and ²³²Th); explosives compounds (cyclotetramethyltetramine [HMX], and hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX]; total organic carbon (TOC); total organic halides (TOX); purgeable organic compounds (EPA Method 624); extractable organic compounds (EPA Method 625); pesticides (EPA Method 608); total dissolved solids (TDS); specific conductance; water temperature; pH; and water table elevation. Tables 8-46 and 8-47 in Volume 2 list the compliance COCs measured in ground water in the vicinity of Pit 1.

During the first quarter of 1996, no permitted concentration limit was exceeded by validated measurements (Christofferson and MacQueen 1996a). During the second quarter of 1996, a barium concentration of 28 µg/L in a ground water sample from Pit 1 monitoring Well K1-04 exceeded the 25 µg/L concentration limit for that well. (For reference, the MCL for barium in drinking water is 1000 µg/L.) Additional sampling and analyses during the second quarter confirmed the presence of barium (Christofferson and MacQueen, 1996b). However, two subsequent quarterly analyses did not detect barium. Barium occurs naturally in ground water at Site 300 (Webster-Scholten 1994; Taffet et al. 1996), and its presence in the vicinity of Pit 1 is most likely due to natural sources in the rocks.

During the third quarter of 1996, a total uranium activity of 0.23 Bq/L exceeded the 0.13 Bq/L concentration limit for ground water samples from monitoring Well K1-02B, and a tritium activity of 16.58 Bq/L exceeded the 11.43 Bq/L concentration limit for ground water samples from monitoring Well K1-03 (Christofferson and MacQueen,



8

Ground Water

1996c). Previously conducted analyses of uranium by mass spectroscopy at LLNL show that the uranium activity in Pit 1 ground water is due to natural uranium. The tritium activity is related to the previously described tritium plume that originates in soil moisture beneath the Building 850 firing table, about 1 km upgradient from Pit 1 (**Figure 8-10**). The relatively elevated tritium activity measured in ground water from Pit 1 monitoring Well K1-03 signifies that the leading edge of the tritium plume has reached this well. Two other wells in the Pit 1 monitoring network are affected by the encroaching plume: K1-02B and the upgradient Well K1-01C.

During the fourth quarter of 1996, no concentration limits were exceeded by validated measurements. As in the past, 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113) appears in ground water samples from Pit 1 monitoring Wells K1-05 (41 µg/L), K1-08 (98 µg/L), and K1-09 (150 µg/L). (For reference, the MCL for Freon 113 in drinking water is 1200 µg/L.) The Freon is not from Pit 1. Rather, it is linked to past spills of Freon in the Advanced Test Accelerator area (**Figure 8-9**; Webster-Scholten 1994; Taffet et al. 1996). Although several COCs have shown statistically significant evidence of release from Pit 1 (Volume 2, Table 8-46), ground water monitoring has yet to produce compelling evidence for the release of any COC to ground water from Pit 1.

Pit 7 Complex Area

Nine compliance wells monitor the Pit 7 Complex comprising four adjacent closed landfills that are covered, but are unlined (**Figure 8-11**). Pits 3, 4, and 5 were closed before RCRA became effective. Pit 7 was closed under RCRA during 1992–93. The complex of closed landfills is located in the Pit 7 Complex Valley. From 1963 to 1988, the landfills received waste gravels from firing tables at Site 300. The gravels contained concrete, cable, plastic, wood, tritium, depleted uranium, beryllium, lead, and other metals in trace amounts. In 1988, 9440 cubic meters (12,350 cubic yards) of gravel were removed from six firing tables at Site 300 and were placed in Pit 7 (Lamarre and Taffet 1989). These were the last solid wastes to be placed in landfills at Site 300. (Since 1988, spent firing table gravels are shipped to LLNL's Nevada Test Site for disposal.)

RCRA closure of Pit 7 was completed in February 1993. Closure included construction of a cap, runoff diversion channels, and a ground water interceptor trench to reduce local ground water recharge from rain.

Ground water beneath the Pit 7 Complex Area flows east-northeast, following the dip of the underlying sedimentary rocks.

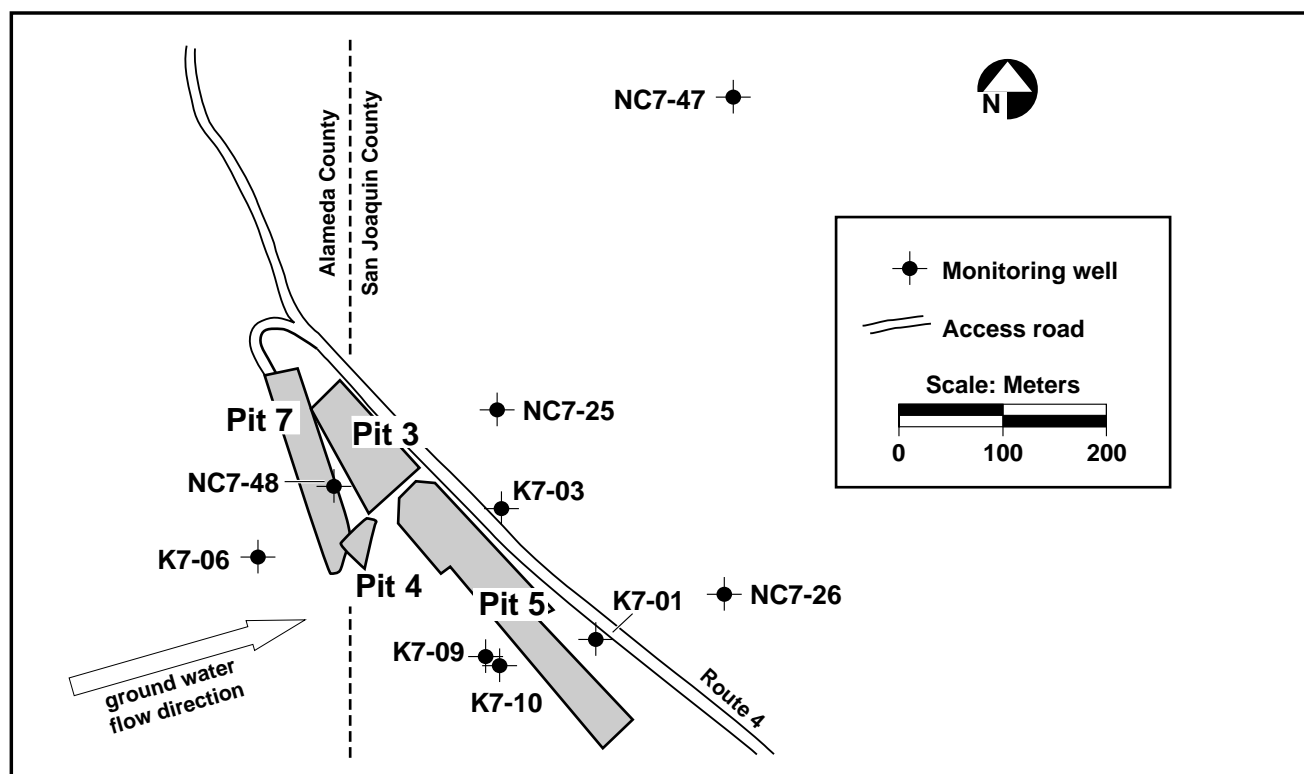


Figure 8-11. Locations of compliance ground water monitoring wells, Pit 7 Complex.

Monitoring Well K7-06 is hydrologically upgradient from Pit 7, Wells K7-09 and K7-10 are cross-gradient, and Wells K7-01, K7-03, NC7-25, NC7-26, NC7-47, and NC7-48 are downgradient. Wells K7-01, K7-10, and NC7-26 are completed in the Neroly lower blue sandstone (Tnbs₁). The remaining wells are completed beneath Tnbs₁ in the Cierbo claystones and sandstones (Tmss).

For compliance monitoring during 1996, ground water samples were taken quarterly from Pit 7 monitoring wells and were analyzed for COCs fulfilling the requirements of WDR Order No. 93-100 Revision 1 (CVRWQCB 1993, 1996) and the RCRA post-closure monitoring plan (Rogers/Pacific Corporation 1990). Measurements were made for various elements, mostly metals; general radioactivity (gross alpha and gross beta); the radioisotopes tritium (³H), radium (²²⁶Ra), uranium (²³⁴U, ²³⁵U, and ²³⁸U), and thorium (²²⁸Th and ²³²Th); explosives compounds (cyclotetramethyltetramine [HMX], and hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX]; volatile organic compounds (EPA Method 601); and ground water elevation. The uranium isotope measurements were summed and are reported as total uranium. The Pit 7 compliance analytical data for 1996 are presented in Volume 2, Tables 8-48 and 8-49.



8

Ground Water

During the first quarter of 1996, a nickel concentration of 5.6 µg/L in the ground water sample from monitoring Well K7-09 exceeded the 5 µg/L concentration limit for that well. Although one of two retest samples showed nickel above the concentration limit, three subsequent quarterly analyses during 1996 did not detect nickel. No third or fourth quarter analysis detected nickel in any ground water sample from Pit 7 monitoring wells.

During the second quarter of 1996, no concentration limits were exceeded by validated measurements. However, total uranium activity in the ground water samples from Wells NC7-25 (0.77 Bq/L) and NC7-48 (0.87 Bq/L), exceeded the 0.74 Bq/L MCL for drinking water.

A CERCLA uranium characterization of ground water at Site 300, begun in 1994, was completed in 1996 (Taffet et al. 1996). The characterization was undertaken to determine the extent of “depleted” uranium, or D-38, in the ground water across the northern half of Site 300. D-38 was discovered in 1993 in ground water samples from Pit 7 monitoring Well NC7-48 (Christofferson et al. 1993). The subsequent CERCLA uranium study identifies Pit 5, Pit 7, and the Building 850 firing table gravels as three likely sources of D-38 in the ground water (Taffet et al. 1996). The CERCLA study further concludes that D-38 was released from Pits 5 and 7 during the wetter-than-normal winter of 1982–1983, when above normal rainfall and local ground water recharge caused the water table to rise into contact with solid wastes in the two landfills.

The addition of small amounts of D-38 to ground water already containing considerable natural uranium has resulted in total uranium activities in excess of the 0.74 Bq/L (20 pCi/L) California MCL for drinking water. Two small, shallow plumes of ground water with total uranium activity exceeding 0.74 Bq/L are shown in **Figure 8-12**. Interestingly, spectroscopy measurements indicate that natural uranium is the primary source of total uranium activity in ground water at Well NC7-25, whereas D-38 is the major component of total uranium in the ground water at Well NC7-48. A substantial source of natural uranium is indicated in the aquifer rocks.

During the third quarter of 1996, a routine measurement of copper in the ground water sample from monitoring Well K7-03 exceeded the concentration limit for copper and was initially reported to the CVRWQCB as indicating “statistically significant evidence for a release.” However, subsequent analyses showed copper concentration below the concentration limit (Christofferson and MacQueen 1996c). During the fourth quarter of 1996, no concentration limits were exceeded by validated measurements.

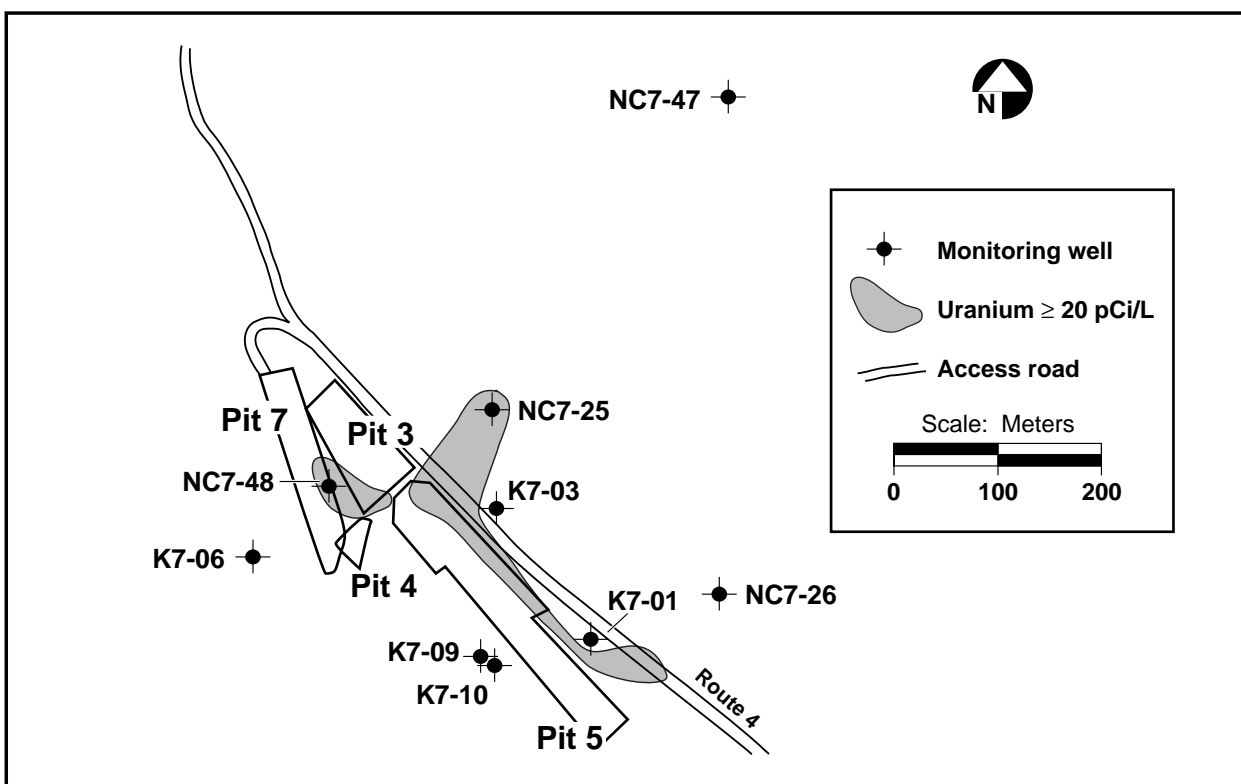


Figure 8-12. Map of the Pit 7 Complex showing two shallow ground water plumes where uranium is in excess of the California MCL for drinking water.

During all of 1996, as in the past, tritium activities in ground water samples from three Pit 7 wells exceeded the 740 Bq/L drinking water MCL. These wells are K7-01, K7-03, and NC7-25. LLNL remedial investigators conclude that tritium was released during the unusually wet winter of 1982–83 from sources in Pits 3 and 5 (Webster-Scholten 1994) with additional minor releases occurring during the wet winters of 1992–93 and 1994–95 (Taffet et al. 1996). The highest tritium activity measured in 1996 was 13,900 Bq/L in a third-quarter sample from monitoring Well NC7-25. This peak activity is 37% higher than the 10,175 Bq/L maximum activity measured in samples taken during 1995. The increasing activity supports other evidence that minor releases of tritium occurred from Pits 3 and 5 during recent wet winters. Monitoring Well NC7-25 is located close to tritium sources in Pits 3 and 5 (**Figures 8-10 and 8-11**). The 1996 peak tritium activity is 19 times the MCL for tritium in drinking water. However, none of the wells supplies water for drinking or irrigation in the area affected by the released tritium.

During 1996, as in previous years, TCE was detected below the 5 µg/L MCL for drinking water in ground water samples from Wells K7-01 and K7-03. 1,1-DCE was detected below its 6 µg/L MCL in ground water samples from Well K7-03, and Freon 11 was detected at 1.1 µg/L, far below its 150 µg/L MCL, in ground water samples from Well NC7-48. Freon 11 has been detected at similar low amounts in quarterly ground



8

Ground Water

water samples from monitoring Well NC7-48 since the second quarter of 1992, when it was first reported (Fischer et al. 1992). Pit 7 is a potential source of the Freon 11, because it is the only landfill in the Pit 7 Complex that is monitored by Well NC7-48.

The RCRA Closure and Post-Closure Plan (Rogers/Pacific Corporation 1990) requires LLNL to maintain the structural integrity and effectiveness of Pit 1 and Pit 7 containment structures. Both pits were inspected by LLNL technical staff on February 21, May 22, August 29, November 20, December 23, and December 30, 1996. California Regulations (Title 22, Section 66264.228) require an independent annual inspection of RCRA-closed landfills by a state-certified engineer. Both pits were inspected on November 13, 1996, by a qualified engineer who provided a written report of findings. The engineer's findings do not differ significantly from LLNL's self-inspection findings of minimal degradation (Christofferson and MacQueen 1997). To detect uneven settling that might compromise the watertight integrity of the pit caps, the elevations fixed markers on the caps were measured by LLNL surveyors on December 17, 1996. The maximum measured settlement is 1 cm for the Pit 1 cap, and 2 cm for the Pit 7 cap.

Surface Impoundments

Release Detection

A three-tiered monitoring network is in place to any detect releases of chemicals from the surface impoundments in the Explosives Process Area. The primary means of release detection consists of weekly visual inspections for leachate flow at the outfalls of perforated pipes installed in a sand layer between the inner impermeable layer liner of high density polyethylene and an outer impermeable liner of compacted clay. Secondary release detection consists of quarterly remote operation of lysimeters installed beneath the clay liners. Monitoring wells comprise a tertiary release detection system and a means of estimating the environmental impact on ground water. Data pertaining to water in the surface impoundments are found in Volume 2, Tables 8-51 to 8-57.

Leachate Collection. The two leachate collection and removal systems (LCRS) were monitored for the presence of liquids, which would indicate a leak in a surface impoundment liner. As previously reported (Harrach et al. 1996), a leak was discovered in the upper surface impoundment's polyethylene liner in June 1995. The leak allowed water to seep into a leachate collection pipe and from an outlet pipe into the lower surface impoundment. Although repairs to the system were completed in December 1995, water continued to flow from the upper surface impoundment's leachate collection system into September 1996. This residual leachate had collected in the sand layer between the two liners of the surface impoundment. From the highest leachate flow rate of 47 L/day on August 9, 1995, the leak rate fell to zero by October 3, 1996, and has remained at zero.



Lysimeters. Five lysimeters installed in the vadose zone beneath the liners of the impoundments were operated quarterly during 1996 to extract water for analysis. No water was recovered. If water had been found in the lysimeters or the leachate collection systems, it would have been analyzed for aluminum, arsenic, barium, bicarbonate alkalinity, cadmium, calcium, carbonate alkalinity, chloride, chromium, cobalt, copper, fluoride, hydroxide alkalinity, iron, lead, magnesium, manganese, molybdenum, nickel, nitrate, pH, potassium, RDX, HMX, silver, sodium, specific conductance, sulfate, total dissolved solids, total alkalinity, total hardness, and zinc.

Monitoring Wells. The Monitoring and Reporting Program for the surface impoundments (MRP 96-248) requires that ground water samples be collected quarterly from four monitoring wells and establishes concentration limits for COCs in ground water beneath the surface impoundments. MRP 96-248 became effective on September 20, 1996, amending the monitoring and reporting program previously required by MRP 85-188. The COCs and their concentration limits for ground water beneath the surface impoundments are listed in Volume 2, Table 8-52.

WDR 85-188, which was in effect through the first three quarters of 1996, required that ground water beneath the surface impoundments be monitored quarterly at one upgradient and four downgradient monitoring wells for the following COCs: total organic halogens (TOX), total organic carbon (TOC), pH, electrical conductivity, nitrate, nitrite, high explosive compounds (HMX and RDX), nickel, selenium, silver, thallium, vanadium, zinc, molybdenum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, and mercury.

MRP 96-248 requires compliance monitoring of the ground water underlying the two connected surface impoundments (**Figure 8-13**). Four ground water monitoring wells are used. They are screened in the Neroly Formation upper blue sandstone layer (Tnbs₂). The direction of ground water flow is approximately southeasterly, following the local attitude (dip) of the formations. Well W-817-01 is hydrologically upgradient of the surface impoundments. Wells W-817-02, W-817-03, and W-817-04 are downgradient. Ground water samples are collected quarterly from these monitoring wells for analyses of the COCs specified in WDR 96-248. In addition, concentrations of ammonia, bromide, orthophosphate, and TATB will be measured six times during the first year to determine their statistical limits of concentration (SLs). All COC analyses under MRP 96-248 for the fourth quarter 1996, except for nondetections, are presented in Volume 2, Tables 8-57 and 8-58.



8

Ground Water

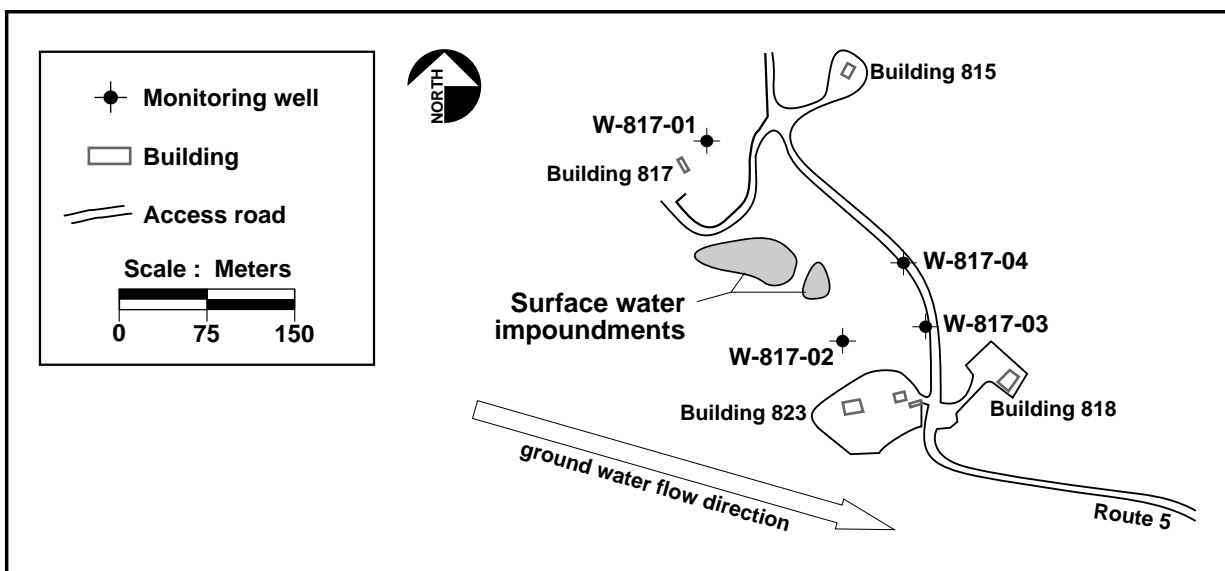


Figure 8-13. Locations of compliance ground water monitoring wells in the Explosives Process Area.

The High Performance Liquid Chromatography method (EPA Method 8330) is used to analyze for energetic compounds. Analyses of ground water from upgradient monitoring Well W-817-01 indicated HMX at concentrations between 14 and 35 $\mu\text{g/L}$. HMX was not detected above the analytical reporting limit of 1 to 5 $\mu\text{g/L}$ in any of the ground water samples from the downgradient monitoring wells. Ground water samples from three wells contained detectable concentrations of the energetic compound RDX above the analytical reporting limit of 0.85 $\mu\text{g/L}$. The ground water samples containing RDX were from upgradient Well W-817-01 (from 21 to 85 $\mu\text{g/L}$) and from downgradient Wells W-817-03 (5 to 8 $\mu\text{g/L}$) and W-817-04 (4.4 to 8.7 $\mu\text{g/L}$). RDX and HMX originate at closed disposal sites upgradient of the present surface impoundments (Raber and Carpenter 1983; Webster-Scholten 1994). The concentrations observed in the downgradient wells do not exceed their SLs. Additional compounds were detected by EPA Method 8330, but do not have SLs or MCLs.

Ground water concentrations of TCE continued to exceed the drinking water MCL of 5 $\mu\text{g/L}$ in samples from Wells W-817-03 and W-817-04 during 1996. The TCE detected in ground water samples from these wells has migrated in the ground water from past spills at Building 815, upgradient of the impoundments (Webster-Scholten 1994). No SL was developed for TCE, because it has not been discharged to the surface impoundments.

Ground water analyses of metals were carried out using inductively coupled plasma and graphite-furnace atomic-absorption spectroscopy EPA methods. Analyses of other inorganics were carried out using other EPA-approved methods. Ground water



concentrations of arsenic and nitrates continued to exceed drinking water MCLs in samples from all the surface impoundment monitoring wells during 1996. Concentrations of both arsenic and nitrates in ground water have historically exceeded their respective MCLs (0.050 mg/L for arsenic and 45 mg/L for nitrates) in this area. Background concentrations of arsenic in ground water monitoring wells upgradient from the surface impoundments have been measured at concentrations above the drinking water MCL (Webster-Scholten 1994). Because of the wide range of measured concentrations, arsenic is the only compound for which statistical analysis of variance (ANOVA) is used each quarter to determine if a significant increase has occurred. For ANOVA, four individual samples are collected from each well and analyzed for arsenic. To date, ANOVA indicates no significant differences in arsenic concentrations upgradient and downgradient from the surface impoundments. The distribution of arsenic over time and throughout the area suggests a natural source.

For the other COCs, analytical results are reported with the statistical method used, the SL, and the fourth quarter 1996 data in Volume 2, Tables 8-57 and 8-58.

Concentrations of zinc analyzed in ground water samples from monitoring Well W-817-02 exceeded the SL of 0.076 mg/L for zinc during the fourth quarter. The concentration of zinc in the sample collected October 1 was 0.14 mg/L. Two confirmation samples were collected in December. Zinc concentrations of 0.12 and 0.22 mg/L in these ground water samples confirmed the initial result.

However, the increase in zinc in ground water samples from monitoring Well W-817-02 could represent a release of zinc from sources other than the surface impoundments for the following reasons:

- Zinc was not detected above the analytical reporting limit of 0.02 mg/L in four separate samples of leachate taken from the upper surface impoundment LCRS in June 1995 (Christofferson and MacQueen 1995).
- Wastewater samples collected from within the upper surface impoundment on April 13 and June 30, 1995, indicated zinc concentrations of <0.02 mg/L to 0.072 mg/L, respectively; a sample taken from the lower surface impoundment on April 13, 1995, contained zinc at a concentration of 0.021 mg/L (Fisher 1995). These concentrations are below those found in the ground water samples from monitoring Well W-817-02 in October through December 1996.
- Historical monitoring data show zinc concentrations as high as 0.25 mg/L in ground water samples from background (or upgradient) monitoring Well W-817-01 in a sample collected in April 1988, and 0.21 mg/L in a sample collected in October 1989. Likewise, zinc concentrations of 1.0 mg/L and 0.75 mg/L were found in samples collected from ground water monitoring



Wells W-817-02 and W-817-03, respectively, on February 6, 1989. These higher zinc concentrations indicate either natural variation or are the result of past human activities upgradient of this area. In either instance, they are not associated with the surface impoundments.

Influent Monitoring

Photographic Process Rinse Water Discharges. WDR 96-248 established new limits for discharges into the surface impoundments and required monitoring of the photoprocess and chemistry area wastewater retention tanks that discharge to the surface impoundments, as well as direct discharges occurring from the Explosives Process Area to the surface impoundments. Table 8-52 in Volume 2 identifies the limits applicable to discharges into the surface impoundments. During 1996, all discharges into the surface impoundments were consistent with these discharge limits.

Retention tanks containing photographic process rinse water from Buildings 801, 823, 850, and 851 are sampled to confirm that discharges are consistent with the limitations specified in WDR 96-248. Discharges to the surface impoundments occur after samples are collected. Rinse water from the Building 823 retention tanks is discharged automatically to the surface impoundments. Monitored constituents for the photographic processes, as listed in Volume 2, Table 8-53, were all below discharge concentration limits (Volume 2, Table 8-54).

Chemistry Area Wastewater Discharges. Wastewater from the Chemistry Area (Buildings 825, 826, and 827 Complex) is held in retention tanks until analytical results indicate compliance with the WDR. Monitored constituents are listed in Volume 2, Table 8-53. Analyses of discharges from the Chemistry Area during 1996 are presented in Volume 2, Table 8-55. While all of the discharges during the first three quarters of 1996 occurred prior to the adoption of WDR 96-248, they met the requirements of WDR 96-248. In addition to discharges from retention tanks at the above facilities, wastewater from similar processes at these facilities was contained in drums and then discharged to the surface impoundments. These discharges also met the concentration requirements of WDR 96-248. (See Volume 2, Table 8-56.)

Explosives Process Area Discharges. Process water discharges to the Explosives Area impoundments are analyzed for constituents that have been found (or are likely to be found) in the process water from each specified building within the Explosives Process Area. As shown in Table 8-53, Volume 2, this monitoring program includes photographic process wastewater from Buildings 801, 823, 850, and 851; Chemistry Area wastewater from Buildings 825, 826, 827A, 827C, and 827E; and process area wastewater from Buildings 806/807, 809, and 817.



Explosives Process Area discharges were not sampled in the final quarter of 1996. WDR 96-248 requires annual analysis of this waste stream at Buildings 806/807, 809, and 817. Constituents to be analyzed include metals, VOCs, semivolatiles, and energetic compounds listed in Table 8-52 in Volume 2.

Sewage Evaporation and Percolation Ponds

The environmental monitoring required for the sewage evaporation and percolation ponds is also specified in MRP 96-248. In response to this permit, a new compliance network was formed that involves analyses of wastewater and ground water. Quarterly samples of wastewater flowing into the sewage evaporation pond are collected and analyzed for pH, electrical conductivity, and dissolved oxygen. Observations of the pond are made at least monthly for freeboard, color, odor, and levee condition. All overflow discharges to the percolation pond are sampled and analyzed for biochemical oxygen demand, electrical conductivity, total and fecal coliform, and pH. No overflow occurred during the fourth quarter of 1996.

Samples were collected from wastewater flowing into the evaporation pond and from the pond itself on December 19, 1996. All of the monitored constituents are in compliance with permitted limits.

Ground water monitoring includes semiannual sampling and analysis from upgradient monitoring Wells W-7E, W-7ES, and W-7PS; from cross-gradient ground water monitoring Well W-35A-04; and from downgradient ground water monitoring Wells W-26R-01, W-26R-11, W-26R-05, W-25N-20, and W-7DS (**Figure 8-14**). Monitoring Wells W-7PS, W-26R-11, and W-35A-04 are screened in Quaternary alluvium (Qal); Wells W-7E and W-26R-01 are screened in the Tnbs₁; the four remaining wells are screened in both Qal and Tnbs₁. Ground water samples were collected from the wells on November 5th and 14th and analyzed for electrical conductivity, nitrate, total and fecal coliform, and pH, and general minerals. The ground water analytical data for the sewage pond monitoring network are presented in Volume 2, Table 8-58. All of the monitored constituents are in compliance with permitted limits. Background measurements for electrical conductivity and total dissolved solids exceed their respective California Secondary MCLs. Concentrations of TCE of 15 µg/L in ground water from monitoring Well W-26R-01 probably originated at an upgradient debris burial trench (Webster-Scholten 1994).

MRP 96-248 requires monthly inspections of the percolation pits at Buildings 806A, 827A, 827C, 827D, and 827E. It also requires sampling and analysis for metals if an overflow occurs. Inspections began in December 1996. No overflows or problems with pit operations were observed.

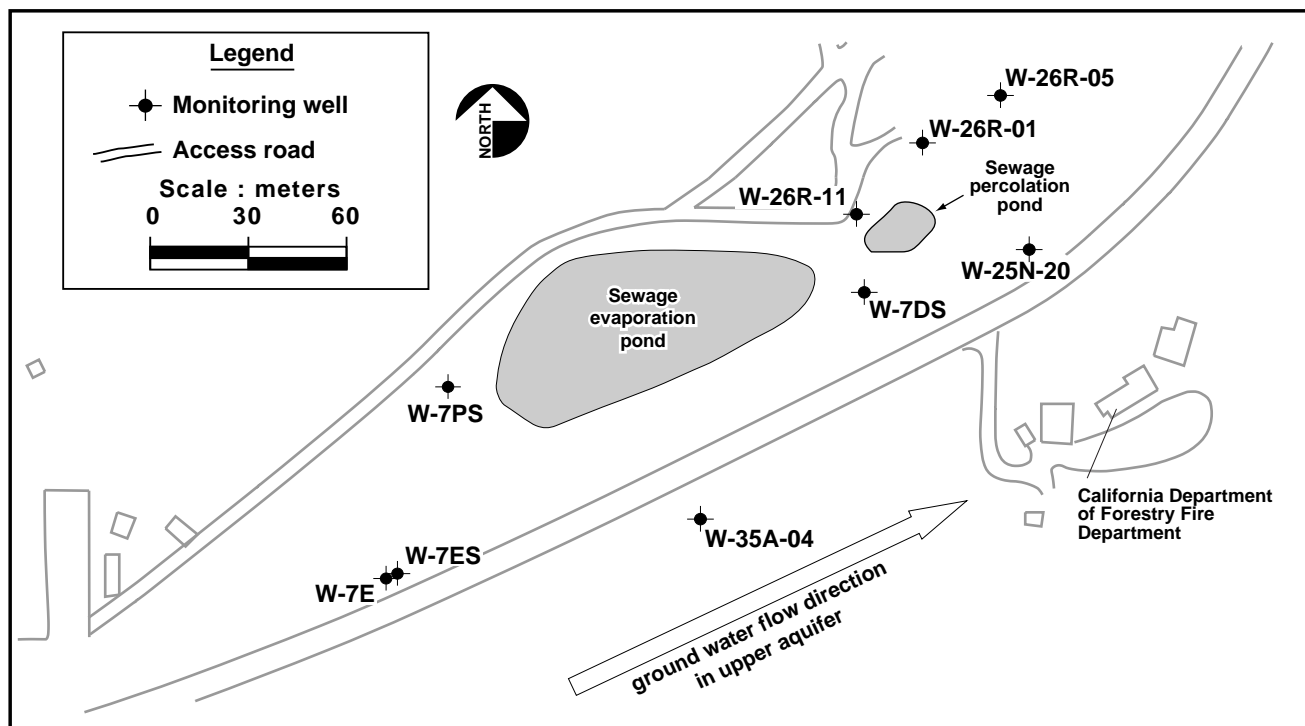


Figure 8-14. Locations of compliance ground water monitoring wells in the area of the sewage ponds.

Ground Water Remediation

This section discusses monitoring driven by permits or equivalent documents.

Livermore Site

Treatment Facility A (TFA) is located in the southwestern part of LLNL near Vasco Road (**Figure 7-16**, Chapter 7). At TFA, VOCs are removed from ground water using UV/H₂O₂ treatment technology and an air stripper. Extracted vapors are removed using vapor extractor with granulated activated-carbon canisters. In operation since September 1989, TFA has treated more than 1000 ML of ground water, removing about 75 kg of VOC mass from the subsurface. During 1996, TFA treated about 350 ML of ground water containing an estimated 16.8 kg of VOCs. Treated ground water was discharged to the Recharge Basin located about 600 m southeast of TFA on DOE SNL/California property.

TFA is currently processing ground water at a rate of about 1136 L/min from 18 extraction wells. Once TFA has been modified to treat ground water with air stripping only, its capacity will be increased to 1325 L/min. Modification of TFA is scheduled for spring 1997 (Hoffman et al. 1997). Other treatment facilities are discussed in Chapter 7.



Waste Discharge Requirement (WDR) No. 88-075 requires a sampling program for this facility (**Table 8-4**). In 1996, new extraction wells were plumbed into TFA to accelerate the rate of ground water extraction and cleanup. However, because of the increased flow of ground water through the treatment facility, contaminants were not always completely destroyed. Self-monitoring analytical results of TFA effluent samples indicate that the VOC discharge limit of 5 µg/L was exceeded 12 times between July 10 and November 26, 1996, with total VOCs ranging from 5.5 to 7.5 µg/L.

The solution was to scale back the flow rate through the treatment facility to enable us to meet the discharge limits. The exceedances were reported to and discussed with the CERCLA regulatory agencies (USEPA, California DTSC, and the California RWQCB) at regularly scheduled monthly CERCLA Remedial Project Managers' meetings and documented in the minutes of those meetings.

Site 300

Building 834 Complex. The Building 834 Complex is located in the eastern portion of Site 300. An isolated, perched, water-bearing zone that contains TCE in excess of the MCL of 5 ppb has been defined and reported (Bryn et al. 1990; Landgraf et al. 1994). The TCE remediation system at this site is operated as a Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Removal Action. Ground water treatment and discharge is monitored in compliance with the Regional Water Quality Control Board (RWQCB) Substantive Requirements for the B834 Removal Action. Air emissions are stipulated to be no greater than 6 ppm/hr, and are regulated under an Authority to Construct permit from the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD). Limitations on effluents discharged from ground water treatment operations are listed in **Table 8-5**.

Techniques to remove TCE vapor from the vadose zone above the water table and from the shallow perched water have been evaluated and pilot-tested. Water was extracted by pumping from ground water extraction wells and from soil vapor extraction wells under vacuum. Pilot remediation began during 1993 at the Building 834 Complex, where about 300 kg of TCE was removed from the soil vapor in unsaturated sediments and ground water by extraction and treatment. Ground water has been treated by air sparging. Vapor-phase TCE is removed by adsorption on granular activated carbon, although experiments have been conducted at Building 834 to evaluate in-line destruction of TCE with ultraviolet flash lamps and an electron-beam accelerator. During 1993, the pilot extraction system was upgraded in preparation for a CERCLA Removal Action. Proof-of-system testing was conducted during 1994. During 1995, 9700 L of ground water were extracted to treat 0.36 kg of VOCs (primarily TCE) by air sparging.



8

Ground Water

Table 8-4. Treated ground water discharge limits identified in WDR Order No. 88-075 for TFA.

Constituent	Discharge limit ^(a)
Metals (µg/L)	
Antimony	1460
Arsenic	500
Beryllium	0.68
Boron	7000
Cadmium	100
Chromium(III)	1700×10^3
Chromium(VI)	500
Copper	2000
Iron	3000
Lead	500
Manganese	500
Mercury	20
Nickel	134
Selenium	100
Silver	500
Thallium	130
Zinc	20,000
Volatile organic compounds (µg/L)	
Total volatile organic compounds	5
Acid extractable organic compounds (µg/L)	
2,4-Dimethylphenol	400
Phenol	5
2,4,6-Trichlorophenol	5
Base/neutral extractable organic compounds (µg/L)	
1,4-Dichlorobenzene	5
Naphthalene	620
Phenanthrene	5
Pyrene	5

^a These limits are instantaneous maximum values.



Table 8-5. Site 300 Building 834 ground water treatment surface discharge effluent limitations.

Parameter	Building 834 Treatment Facility
VOCs^(a)	
Maximum daily (per compound)	5.0 µg/L
Monthly median	0.5 µg/L
pH	Between 6.5 and 8.5
Location discharge	Treated effluent will be discharged by air misting east of Building 834.
Total petroleum hydrocarbons	
Daily maximum contaminant level	100 µg/L
Monthly median	50 µg/L
Flow rate (30-day average daily dry weather maximum discharge limit)	7580 L
Mineralization	Mineralization must be controlled to no more than a reasonable increment.
Methods and detection limits	
VOCs	Method EPA 601/602 ^(b)
Tetrabutyl orthosilicate (TBOS)	Modified EPA Method 8015, discharge limit = 100 µg/L ^(c)

^a The sum of VOC concentrations in a single sample shall not exceed 5.0 µg/L.

^b Confirmatory VOC identifications were sometimes required during treatment facility characterization, and EPA 624 analyses were requested in addition to the EPA 601/602 analyses.

^c Detection limits for TBOS are currently ~100 µg/L by a modified EPA 8015 procedure.

During 1996, 156,245 L of ground water were extracted to treat 10.7 kg of VOCs (96% TCE). The resulting clean effluent water was discharged to air by an elevated mister network located immediately southeast of the Building 834 Complex. This unique design allows for the rapid evaporation of the clean effluent water and prevents surface erosion and ground water recharge.

The extraction system underwent extensive expansion and upgrading during 1996. Nine additional wells were plumbed into the manifold, bringing the total number of extraction wells to 15. A number of engineering modifications were implemented to simplify management of off-gas scrubbing and the associated monitoring. A sheltering roof was erected over the treatment apparatus to divert rainwater away from the area of highest subsurface contamination, greatly reducing recharge in that area. An economical plan was also developed for further drainage improvements and road surface repairs to further reduce recharge into the contaminated area.



8

Ground Water

Collaborative research efforts with scientists and engineers at the Oregon State University Department of Civil Construction and Environmental Engineering began in 1996. The collaboration team will characterize the biological breakdown of VOCs in the area, surfactant behavior in local sediments, the use of naturally occurring radon gas as a tracer of residual hydrocarbons, the feasibility of promoting anaerobic TCE dechlorination by supplying electron acceptors, and existing biological processes in the subsurface.

During full scale operation of the treatment system, all compliance requirements for treated ground water and air emissions were met. Moreover, no organic compounds were detected for any effluent water samples during 1996.

Ground Water Protection Management Program

LLNL's Ground Water Protection Management Program (GWMP) is a multifaceted effort to eliminate or minimize adverse impacts of LLNL operations on ground water (Failor and Isherwood 1994). U.S. Department of Energy (DOE) Order 5400.1 and the soon-to-be promulgated 10 CFR 834 require all DOE facilities to prepare a GWMP that describes the site's ground water regime, programs to monitor the ground water and monitor and control potential sources of ground water contamination, and areas of known contamination and remediation activities. Much of the ground water monitoring and remediation at the Livermore site is carried out under Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) restoration efforts, and the Livermore Site Ground Water Project and is summarized in Chapter 2 of this document. This section describes the site's ground water regime, programs to monitor the ground water and to monitor potential sources of ground water contamination, and programs to control potential sources of contamination.

Areas of Special Concern

The objectives of the GWMP include monitoring the impact of current operations and eliminating or minimizing adverse impacts from ongoing operations on ground water. The approach is to detect contaminants before they can enter the ground water. To do this, areas have been identified that are contaminated or potentially contaminated with hazardous and/or radioactive waste, focusing on four areas:

- Geologic areas with rapid communication between surface water and ground water.
- Current processes and operations that could contaminate areas of rapid contamination.



- Current and planned best management practices (BMPs) that minimize the risk of ground water contamination.
- Current and new monitoring to provide early warning of potential ground water contamination.

With these considerations, five areas have been identified as being at risk for ground water contamination:

- The arroyos (Arroyo Las Positas and Arroyo Seco) that cross the site.
- The storm drain system.
- Soil around underground storage tanks.
- Soil around the sanitary sewer systems.
- The ground water beneath the hazardous waste management (HWM) buildings, B514 and B612 that may be subject to spills.

Soil and Sediment Surveillance Monitoring

Soil monitoring in the arroyos and storm water network was one of the items targeted in the GWMPMP surveillance monitoring because "...recharge of natural runoff through the stream beds of arroyos accounts for the majority (about 42%) of resupply to the Livermore Valley ground water basin..." (Webster-Scholten 1994). Infiltrating rainwater may carry with it any dissolved constituents that may be present. Programs already exist that address the sanitary sewer system, the building drains, and underground storage tanks.

LLNL has developed background levels for total metals in soils and sediments and de minimis (or designated) concentration levels for soluble metals and organics (Marshack 1991). This designated level methodology (DLM) determines the soluble levels of contaminants that would not adversely impact ground water beyond its beneficial uses by application of a simple attenuation factor and specific water quality objectives. The San Francisco Bay Regional Water Quality Control Board (RWQCB) and LLNL agreed upon an attenuation factor of 100 except for certain metals; the attenuation factor for copper, lead and zinc is 1000. Any constituents with soluble concentrations above these de minimis levels may adversely impact the ground water beneath. LLNL has developed and the San Francisco Bay RWQCB has approved a site-specific DLM for beneficial reuse of soils generated from construction projects at the Livermore site. If the concentration of a constituent in soil is above its background level, the DLM can be used to determine if the concentration is protective of ground water quality.



In 1996, LLNL sampled shallow vadose zones in the arroyos at two influent locations (ALPE and GRNE), and the two effluent locations (ASW and WPDC) corresponding to storm water sampling locations. In addition, sediment samples were collected from locations CDB and CDB2 in the settling basins upstream of the Drainage Retention Basin (see **Figure 7-1**, Chapter 7). Samples were analyzed for both total and soluble metals using California's Waste Extraction Test. For a description of methods and a discussion of 1996 arroyo sediment sampling radiological results, see Chapter 9. The only constituent found above background was mercury at location CDB (0.16 mg/kg compared to a background concentration of 0.11 mg/kg). The DLM indicated that mercury was at levels that would not impact beneficial use of ground water. Thus, the sediment data indicate no adverse impact on ground water through the arroyos that cross the Livermore site.

CERCLA Remedial Actions

Livermore Site

An extensive investigation of the remediation options for the contaminated areas discussed above is summarized in the *CERCLA Feasibility Study Report for the LLNL Livermore Site* (Isherwood 1990). The Record of Decision (ROD) for Lawrence Livermore National Laboratory Livermore Site (U.S. Department of Energy 1992) documents the remedial options selected for implementation. The selected remedies for ground water contamination involve pumping the ground water to the surface for treatment with a combination of ultraviolet-light hydrogen peroxide, air stripping, and granulated activated carbon. The selected remedies for contaminants in the unsaturated zone are vacuum-induced venting with surface treatment of the vapors by catalytic oxidation or activated-carbon filtration. The goal of the remedial action is to clean the ground water to the levels specified in the applicable, relevant, and appropriate requirements developed for this project and outlined in the ROD. A description of the remediation efforts during 1996 can be found in Chapter 2 of this document.

Site 300

Investigation of the remediation options for the contaminated areas at Site 300 is discussed in the Final SWRI Report (Webster-Scholten 1994). It includes a thorough compilation of all pre-1992 ground water and soil investigation information for the entire site and contains a detailed assessment of potential human health and ecological hazards or risks resulting from contamination of soil, rock, and ground water. New characterization, summary, and feasibility study or engineering evaluation/cost analysis reports have been, or will be, prepared for portions of the individual study areas, where the Final SWRI Report or more recent studies indicate that unacceptable potential hazards or risks exist. A summary of the remediation efforts and studies conducted during 1996 can be found in Chapter 2 of this document.



Environmental Impacts

The impact of LLNL Livermore site and Site 300 operations on off-site ground waters is minimal. With the exception of VOCs being remediated under CERCLA at both sites, LLNL operations appear to have little or no adverse effect on the surrounding ground waters.

Livermore Site

No ground water in any of the off-site wells monitored exceeded primary drinking water MCLs for any of the monitored constituents. A possible exception is bis (2-ethylhexyl)phthalate (DEHP), which was found in concentrations of 19 and 14 $\mu\text{g/L}$ (above the drinking water MCL of 4 $\mu\text{g/L}$) in March and August ground water samples from monitoring Well W-571. Since this compound is known to be a common laboratory contaminant, it is possible that it may have been introduced during chemical analysis. LLNL will determine the origin of DEHP in Well W-571 through further studies during 1997.

None of the radioactivity data exceeded MCLs. Of the potential radiological contaminants, radium in downgradient monitoring Well W-1012 was the closest (83%) to its MCL. The maximum tritium activity (13.95 Bq/L), about 1.9% of the MCL, was detected in the ground water sample from off-site Well 11B1.

Of the Livermore on-site monitoring wells, no inorganic data exceeded primary MCLs, with the exceptions of chromium in monitoring well W-373 and nitrates in monitoring well W-1012. Chromium(VI) in ground water in the vicinity of Monitoring Well W-373 is being treated in TFC, and this treatment is monitored separately. Chromium(VI) concentrations have been decreasing since TFC began operations (1993). An investigation to determine the source of nitrate in the vicinity of W-1012 is continuing. Although VOC discharge limits were exceeded at TFA, the environmental consequences were negligible.

Site 300

Compliance and surveillance monitoring at Site 300 and adjacent properties in the Altamont Hills leave little doubt that LLNL operations have minimal impact on ground water beyond the site boundaries.

Tritiated water and depleted uranium have been released to ground water from inactive landfills and from an active firing table at Site 300. The boundaries of the contaminated ground water lie entirely within the site boundaries. Fate and transport models predict that the tritium will decay naturally to an activity below the drinking water MCL before the tritium-bearing ground water reaches a site boundary (Webster-Scholten 1994; Taffet et al. 1996).



8

Ground Water

Maximum uranium activities that could reach potential exposure points (hypothetical ground water supply wells) at the northern boundary of Site 300 are estimated to be 0.08 Bq/L from plumes originating at Pits 5 and 7, and 0.05 Bq/L at the eastern boundary of Site 300 from the plume originating at Building 850. These conservatively estimated maximum activities are small when compared with the 0.74 Bq/L California MCL for uranium in drinking water. The predicted incremental lifetime cancer risks from the released uranium are less than one-in-a-million at the hypothetical exposure points on the Site 300 boundary (Taffet et al. 1996). The tritium and uranium in the ground water beneath Site 300 present no current health risks, because the water is neither used for agriculture nor consumed by people or cattle.

TCE has been released to ground water at numerous locations at Site 300 (see Chapter 2, **Figure 2-2**; Webster-Scholten 1994). With the exception of the plume extending off site from the Eastern GSA area, all of the TCE-bearing ground water is on site. This water is being pumped back to the site and quickly cleansed of TCE.